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CONTENTS

Pages

Fossil fresh-water mollusks and ecological interpretations. By Teng-Chien Yen.. 1375–1380

Ocean-bottom photographs of the neritic and bathyal environment south of Cape Cod, Massachusetts. By John Northrup..... 1381–1384

Deformation of Yule marble: Part IV—Effects at 150°C. By David Griggs, Francis J. Turner, Iris Borg, and John Sosoka..... 1385–1406

Short Notes

Submarine topography in the North Atlantic. By Bruce C. Heezen, Maurice Ewing, and D. B. Ericson..... 1407–1410

Mechanism of weathering—a reply. By A. F. Frederickson..... 1411–1412

Submarine erosion, a discussion of recent papers. By Francis P. Shepard..... 1413–1418

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PAPERS IN PRESS FOR FORTHCOMING ISSUES

EARLY CENOZOIC STRATIGRAPHY AND VERTEBRATE PALEONTOLOGY OF THE HOBACK BASIN, WYOMING By John A. Dorr

METAMORPHIC FACIES IN THE WISSAHICKON SCHIST NEAR PHILADELPHIA, PENNSYLVANIA. By Dorothy Wyckoff

CAROLINA BAYS AND THEIR ORIGIN. By W. F. Prouty

BULLETIN OF THE GEOLOGICAL SOCIETY OF AMERICA
VOL. 62, PP. 1375-1380 DECEMBER 1951

FOSSIL FRESH-WATER MOLLUSKS AND ECOLOGICAL INTERPRETATIONS

BY TENG-CHIEN YEN

ABSTRACT

The paper gives examples of recent fresh-water molluscan assemblages from Oneida Lake, New York, Bear Lake, Utah, Potomac River at Great Falls, Maryland, and the Forest Stream of the Susaa, Denmark; and fossil assemblages from lake deposits of the Truckee and the Tulare formations, and river deposits of the Kootenai and the Fort Union formations. A correctly identified assemblage of forms from a single deposit of more or less uniform lithology is suggested as a basis for ecological interpretation. Such an assemblage should be analyzed in the light of the known ecological criteria.

CONTENTS

TEXT Page

Introduction 1375
Acknowledgments 1375
Types of living and fossil molluscan assemblages 1375
Bases of ecological interpretations 1378
References cited 1380

INTRODUCTION

Ecology may be briefly defined as a study of the relationship of animals and plants to their environment. The basic method is to procure accurate data (which may be checked if necessary by repeating the experimentation, field observation, and collecting of such data) of physical and biological nature for a specific problem under consideration. The problem may be analyzed and often successfully solved by inductive study of the available data. This method is inapplicable to the study of fossils and their enclosing deposits. Paleoecology, a comparatively new term in natural history, on the other hand, is an analogous study of the organic remains and their enclosing deposits in the light of the known ecological criteria. The basic method is to deduce the ancient environmental conditions from the available data, such as assemblage of fossils, physical properties of the matrix, and stratigraphic information.

The two subjects approach a similar objective by different methods in different fields of material; therefore they are often considerably different in degree of attainment. Paleoecology is at present dependent upon ecology. When sufficient data on fossils have been accumulated, it will provide an additional source of material for dealing with changes of environmental factors in the history of the earth and their effects on organic evolution. The purpose of the present paper is to suggest an elementary but systematic method of collecting such data on fossil fresh-water mollusks as a part of the construction material for building an edifice of paleoecology.

ACKNOWLEDGMENTS

This paper constitutes one of the contributions from a research project (NR-081-097) supported by the Geophysics Branch, Office of Naval Research, Department of Navy. It is carried on under ONR Contract N9-onr-92601 with the Smithsonian Institution, Washington D. C. I wish to offer my hearfelt thanks to G. L. Jepsen, Edwin Kirk, Harry S. Ladd, John B. Reeside, Jr., W. W. Rubey, and L. W. Stephenson, who have kindly read this manuscript and made many useful criticisms. It is natural to have divergent opinion on some issues; however, my appreciation of their kindness goes equally to those in opposition to as well as in favor of the contents of this paper.

TYPES OF LIVING AND FOSSIL MOLLUSCAN ASSEMBLAGES

In inland waters, mollusks are common. However, the distribution of molluscan forms and the variation in quantity of individuals generally form a pattern determined by the habitat. Several typical examples will illustrate the occurrence of different kinds of assemblages

in their respectively different kinds of habitat areas.

On an open wave-washed shore of a lake with a stony beach, the leafy plants are generally scarce, although certain types of algae may form an encrusting growth upon stones, and diatoms are often rather abundant. Under such conditions, species of *Lymnaea*, *Ancylus*, *Neritina*, and the related groups are often very common. However, on a similar kind of shore, but with a sandy beach, mollusks are usually absent.

A quiet littoral zone in a lake, with a gentle slope to a depth of about 20 feet, is often considered a paradise for a lenitic society of organic life. Within the belt of emergent plants, species of aquatic pulmonates are usually common; in the area of floating-leaved plants, species of *Valvata*, *Lymnaea*, *Physa*, and the related genera are the most common of the gastropods, and species of *Sphaerium* and *Pisidium* also attain great abundance; in the growth of submerged plants, rissoid snails are generally abundant, while pulmonates and *Pisidium* are still quite common.

In a sublittoral zone (usually from 20 to 50 feet deep), the molluscan life diminishes rapidly toward the deeper-water area. In the upper portion, species of *Naiades* and *Pisidium*, as well as of *Valvata* and other prosobranchian snails, still live in a great number of places, but toward the lower boundary all but *Pisidium* disappear.

The assemblages of organisms in a river belong of course to a lotic society. They are fitted for life in rapidly moving water, such as currents and waves. In the upper courses, or head streams, molluscan species are much limited in variety. Species of *Lymnaea* and *Bithynella* may often be found crawling over the pebbles, and species of *Anclyus* adhering to the stones. In the lowland courses, molluscan species are considerably more numerous. Species of *Unio*, *Anodonta*, *Margaritifera*, and *Corbicula* are the most common of the bivalves. Species of *Viviparus* and *Goniobasis*, together with those found in the upper courses, are also exceedingly common.

These examples indicate the living membership of different communities in lakes and rivers. After the animals die, their shells generally fall to the bottom, where they are either buried in the sediments or drifted by waves to the shore, where they become part of the shore debris. Occurrences of this sort may be illustrated by several actual examples of drifted assemblages that are found in lakes:

(1) West of Shaw Point on Oneida Lake, New York, according to F. C. Baker (1916), the debris along the beach yielded the following molluscan species (in original nomenclature). The large number of species on shore indicate a multitude of molluscan forms living in this part of lake.

Unionidae:	*Elliptio complanatus* (Dillwyn)
	Lampsilis radiata (Gmelin)
	Lampsilis borealis (Gray)
	Lampsilis iris (Lea)
Sphaeriidae:	*Sphaerium vermontanum* Prime
Viviparidae:	*Campeloma integrum* (DeKay)
Amnicolidae:	*Gillia altilis* (Lea)
	Somatogyrus subglobosus (Say)
	Bithynia tentaculata (Linne)
Pleuroceratidae:	*Goniobasis livescens* (Menke)
Lymnaeidae:	*Galba catascopium* (Say)
Planorbidae:	*Planorbis campanulatus* Say
	Planorbis antrosus Conrad
	Planorbis trivolvis Say
Physidae:	*Physa ancillaria warreniana* (Lea)

(2) At the southeastern end of Bear Lake, Utah (Yen, 1951), the debris on the beach yielded the following species of mollusks:

Sphaeriidae:	*Sphaerium pilsbryanum* Sterki
	Pisidium compressum Prime
Valvatidae:	*Valvata utahensis* Call
	Valvata humeralis californica Pilsbry
Amnicolidae:	*Amnicola longinqua* Gould
	Fluminicola fusca (Haldeman)
Lymnaeidae:	*Lymnaea utahensis* Call
	Lymnaea palustris buttoni Baker
Planorbidae:	*Gyraulus vermicularis* (Gould)
	Helisoma subcrenatum (Cooper)
	Carinifex newberryi (Lea)
Physidae:	*Physa ampullacea* Gould
	Physa sp. undet.

Similarly we have examples to demonstrate patterns of assemblages in the river faunas in the following:

(1) At the Great Falls of the Potomac River, Maryland, the following drifting assemblage of molluscan species was found, however incomplete it may be:

Unionidae:	*Elliptio complanatus* (Dillwyn)
	Lampsilis ventricosa cohongoronta Ortmann
Anodontidae:	*Alasmidonta undulata* (Say)
	Sphaerium stamineum Conrad
Sphaeriidae:	*Pisidium aequilateralis* Prime

	Musculium transversum (Say)
Viviparidae:	*Campeloma decisum* (Say)
	Campeloma rufum (Haldeman)
	Lioplax subcarinatus (Say)
Amnicolidae:	*Amnicola limosa* (Say)
	Amnicola decisa Haldeman
	Gillia altilis (Lea)
Pleuroceratidae:	*Goniobasis virginica* (Gmelin)
	Anculosa carinata (Bruguière)
Lancidae:	*Ferrissia rivularis* (Say)
Planorbidae:	*Helisoma anceps unicarinatum* (Haldeman)
Physidae:	*Physa heterostropha* Say
	Physa gyrina Say

(2) The Forest Stream (Broby Vesterskov) part of the Susaa, Denmark, according to Berg (1948), yielded the following assemblage of molluscan species (in original nomenclature):

Unionidae:	*Unio pictorum* (Linné)
	Unio tumidus Retzius
Anodontidae:	*Anodonta cygnea* (Linné)
Sphaeriidae:	*Sphaerium corneum* (Linne)
	Musculium lacustre (Mueller)
	Pisidium cinereum Alder
	Pisidium nitidum Jenyns
	Pisidium pulchellum Jenyns
	Pisidium subtruncatum Malm
	Pisidium henslowanum (Sheppard)
Valvatidae:	*Valvata piscinalis* (Mueller)
	Valvata cristata (Mueller)
Neritidae:	*Neritina fluviatilis* (Linné)
Viviparidae:	*Paludina vivipara* (Linné)
Amnicolidae:	*Bithynia tentaculata* (Linné)
	Bithynia leachi (Sheppard)
	Bythinella steini Martens
Ancylidae:	*Ancylus fluviatilis* (Linné)
Lymnaeidae:	*Limnaea stagnalis* (Linné)
	Limnaea auricularia (Linné)
	Limnaea ovata Draparnaud
	Myxas glutinosa (Mueller)
Planorbidae:	*Planorbis carinatus* (Mueller)
	Planorbis albus (Mueller)
	Planorbis crista (Linné)
	Planorbis vortex (Linné)
	Planorbis contortus (Linné)
	Planorbis complanatus (Linné)
Physidae:	*Physa fontinalis* (Linné)
	Aplexa hypnorum (Linné)

Among the organic remains, mollusks likewise represent one of the most accessible types of fossils that may be commonly found in continental deposits. Table 1 shows the ranges of the common fresh-water mollusks from Mesozoic to Recent times. The molluscan species often occur in association with ostracodes, oogonia of Characea, fragmentary bones and teeth of fish and higher vertebrates, and not infrequently with leaves and stems of higher plants. Such organic remains form various kinds of biotic assemblages, in various kinds of sedimentary rocks, and in various states of preservation.

Different assemblages of fossil molluscan species are found in the several deposits that are interpreted to represent different kinds of habitat areas. First, we have the following examples to illustrate assemblages in lake deposits:

TABLE 1.—GEOLOGICAL RANGES OF COMMON FRESH-WATER MOLLUSCAN FAMILIES

Molluscan families \ Geologic ages	Late Triassic	Late Jurassic	Early Cretaceous	Late Cretaceous	Paleocene	Eocene	Oligocene	Miocene	Pliocene	Pleistocene	Recent
Pelecypoda											
Unionidae	×	×	×	×	×	×	×	×	×	×	×
Anodontidae	—	—	×	×	×	×	×	×	×	×	×
Sphaeriidae	—	—	×	×	×	×	×	×	×	×	×
Corbiculidae	—	×	×	×	×	×	×	×	×	×	×
Prosobranchiata											
Valvatidae	×	×	×	×	×	×	×	×	×	×	×
Viviparidae	—	×	×	×	×	×	×	×	×	×	×
Ampullariidae	—	—	—	×	×	×	×	×	×	×	×
Amnicolidae	×	×	×	×	×	×	×	×	×	×	×
Neritidae	—	—	×	×	×	×	×	×	×	×	×
Assiminaeidae	—	—	—	—	—	—	—	×	×	×	×
Thiaridae	—	—	×	×	×	×	×	×	×	×	×
Pleuroceratidae	—	×	×	×	×	×	×	×	×	×	×
Pulmonata											
Ellobiidae	—	×	×	×	×	×	×	×	×	×	×
Ancylidae	—	—	—	×	×	×	×	×	×	×	×
Lancidae	—	—	×	×	×	—	—	×	×	×	×
Orygoceratidae	—	—	—	—	—	—	—	×	×	—	—
Planorbidae	—	×	×	×	×	×	×	×	×	×	×
Lymnaeidae	—	×	×	×	×	×	×	×	×	×	×
Physidae	—	×	×	×	×	×	×	×	×	×	×

(1) The Truckee formation, of Pliocene age, 2 miles north of the triangle marking the position of the Desert Queen mine, in the northeastern corner of the Hot Springs Mountains, on the U. S. Geological Survey's Carson Sink topographic sheet, Nevada. The fossil bed yields the following species of mollusks (Yen, 1950):

Sphaeriidae:	*Sphaerium rugosum* Meek
Valvatidae:	*Valvata* cf. *V. incerta* Yen
	Valvata truckeensis Yen
Amnicolidae:	*Amnicola truckeensis* Yen
	Fluminicola yatesiana inflata Yen
	Hydrobia truckeensis Yen
	Lacunorbis nevadensis Yen

Pleuroceratidae:	*Goniobasis sculptilis* (Meek)
	Goniobasis cf. *G. arnoldiana* Pilsbry
Lancidae:	*Lanx undulatus* (Meek)
Planorbidae:	*Gyraulus* sp. undet.
	Menetus sp. undet.
	Vorticifex tryoni (Meek)
	Vorticifex tryoni concavus (Meek)
	Vorticifex tryoni planus Yen
	Vorticifex menetoides Yen
	Vorticifex globosus Yen
	Vorticifex binneyi (Meek)

(2) The basal Tulare formation, of early Pleistocene or late Pliocene in the Kettleman Hills, California. According to Pilsbry (1934), the fossil beds yield the following species of mollusks:

Anodontidae:	*Anodonta kettlemanensis* Arnold
Sphaeriidae:	*Sphaerium cooperi* Arnold
	Sphaerium kettlemanense Arnold
	Pisidium compressum praecompressum Pilsbry
Valvatidae:	*Valvata virens platyceps* Pilsbry
	Valvata humeralis densestriata Pilsbry
	Valvata humeralis californica Pilsbry
Amnicolidae:	*Amnicola longinqua* Gould
	Amnicola puteana Pilsbry
	Fluminicola spiralis Pilsbry
	Fluminicola yatesiana (Cooper)
	Hydrobia andersoni (Arnold)
	Hydrobia andersoni strea Pilsbry
	Hydrobia birkhauseri Pilsbry
	Pyrgulopsis vincta Pilsbry
	Calipyrgula stewardiana Pilsbry
	Calipyrgula carinifera Pilsbry
	Calipyrgula ellipsostoma Pilsbry
	Littoridina woodringi Pilsbry
	Brannerillus involutus Pilsbry
Pleuroceratidae:	*Goniobasis arnoldiana* Pilsbry
	Goniobasis kettlemanensis woodringi Pilsbry
Planorbidae:	*Helisoma? kettlemanense* Pilsbry
	Carinifex sanctaeclarae marshalli Arnold
	Menetus centervillensis (Tryon)
	Planorbifex vanvlecki (Arnold)
Physidae:	*Physa wattsi* Arnold
	Physa humerosa Gould

Second, we have the following examples of molluscan assemblages to represent river deposits:

(1) The Kootenai formation of early Cretaceous age, in the SW ¼ sec. 27, T. 7 N., R. 16 E., about 12 miles southeast of Harlowtown, Montana. The fossil bed yields the following species of mollusks (Yen, 1951):

Unionidae:	*Unio douglassi* Stanton
	Unio farri Stanton
	Unio natosini McLearn
Sphaeriidae:	*Eupera onestae* (McLearn)
Neritidae:	*Mesoneritina* sp. undet.
Amnicolidae:	*Amnicola* sp. undet.
	Reesidella montanaensis (Stanton)
	Stantonogyra silberlingi (Stanton)
	Mesochilina cretacea Yen
Viviparidae:	*Campeloma harlowtonensis* (Stanton)
Pleuroceratidae:	*Circamelania silberlingi* (Stanton)
Planorbidae:	*Gyraulus* sp. undet.
	Anisopsis sp. undet.
Physidae:	*Physa montanaensis* Yen
	Physa sp. undet.

(2) The Fort Union formation, of Paleocene age, at various localities in southern Montana. The fossil beds yield the following assemblage of molluscan species (Yen, 1948):

Unionidae:	*Unio* sp. undet.
	Elliptio cf. *E. priscus* (Meek and Hayden)
	Elliptio cf. *E. silberlingi* Russell
Sphaeriidae:	*Sphaerium* cf. *S. formosum* (Meek and Hayden)
Amnicolidae:	*Fluminicola protea* Yen
Viviparidae:	*Viviparus raynoldsanus* (Meek and Hayden)
	Viviparus trochiformis (Meek and Hayden)
	Viviparus retusus (Meek and Hayden)
	Campeloma nebrascensis (Meek and Hayden)
	Liopiacodes mariana Yen
	Liopiacodes tenuicarinata (Meek and Hayden)
Pleuroceratidae:	*Goniobasis nebrascensis* (Meek and Hayden)
	Goniobasis nebrascensis producta (White)
	Pleurocera warrenanum (Meek and Hayden)
Ancylidae:	*Ferrissia minuta* (Meek and Hayden)
	Palaeancylus radiatus Yen
Lymnaeidae:	*Pleurolimnaea tenuicosta* (Meek and Hayden)
Planorbidae:	*Gyraulus militaris* (White)
	Gyraulus parvulus (Meek and Hayden)
	Carinulorbis planospiralis (Yen)
Physidae:	*Physa* cf. *P. bridgerensis* Meek
	Apleza cf. *A. longiuscula* (Meek and Hayden)

Bases of Ecological Interpretations

In analyzing the assemblages, the differentiation of lake and river deposits cannot be based on the finding of any single species or genus of mollusks, but rather on an assemblage of forms from a single deposit of more or less uniform lithologic characteristics. There is no way to single out any species of fresh-water mollusks

as distinctively a lake or a river form. Common species of *Unio*, *Viviparus*, and *Goniobasis*, which are generally considered river forms, are often found in sizable lakes. Species of *Amnicola*, *Lymnaea*, *Physa*, and *Planorbis*, commonly found in lakes, may frequently occur in a drifting assemblage on the shore of a river. However, if a deposit yields a well-represented assemblage of Unionidae, Sphaeriidae, Viviparidae, and Pleuroceratidae, together with a smaller percentage of pulmonates, it may generally be considered of fluviatile origin. On the other hand, if a deposit contains a large number of Sphaeriidae, Valvatidae, and Amnicolidae, in addition to a well-represented assemblage of aquatic pulmonates, it could probably be considered lacustrine.

A fossil bed that yields an assemblage of a few varieties but with abundance of individuals, including those of younger stages, may well be taken to represent an original habitat area. On the other hand, if it contains a large number of varieties and numerous individuals, it may indicate a drifted assemblage, actually an admixture of littoral and sublittoral forms in addition sometimes to terrestrial species. A sparse number of individuals of Sphaeriidae embedded in a fine-grained matrix may indicate a deposit representing a deep-water facies of a lake, for molluscan life is generally scarce beyond the sublittoral zone, but species of Sphaeriidae are known to exist to a depth of several hundred feet.

An assemblage of fossil forms is thus considered to be one of the most essential bases for ecological interpretation of the fossil-bearing beds. Still there are two supplemental points worth further consideration: the identification of forms, and the reliability of the forms identified.

The identification of forms—a species, for instance—is primarily based on morphological characters; however, physiological and ecological criteria also contribute their part to form the concept of a living species. There is always harmony in every natural unit, and morphological characters are the external expression of such internal harmony. A good example among the fresh-water gastropods from Kouei-tcheou, Szechwan, China is *Helicostoa sinensis* Lamy (1926) and Pruvot-Fol (1937). *H. sinensis* is found on immersed rocks under swift current in rivers. The shells adhere to the rocks shortly after the snails hatch. The initial whorls show normal coiling, while the later ones become irregularly spreding but still firmly attached to the rocks. The adult shell consequently becomes a flattened and disc-like gastropod

Another example may be cited from the Congo Estuary, Africa, *Potodoma agglutinans* Bequaert and Clench (1941) is found, according to the authors in narrow crevices of rocks immersed in swift current. It cements itself to neighboring objects, particularly to the walls of the crevices and other individuals of the same species fixed to the rock in the vicinity. The result is that the shape and growth of the shell become irregularly deformed according to the shape of the wall or other objects.

It is beyond the scope of the present paper to give fuller details here about these rhoephilous gastropods; but both of them show modification of their morphological features that correspond to their ecological conditions.

Opinions may be divergent in regard to the value of the morphological features of the shells as compared to those of the soft parts. However, the shell is a living part of the animal and is equally sensitive to outside influence. The variation of external features follows closely the pattern of its internal structures. Every feature thereon, however minute, undoubtedly has its own meaning to the animal. It is the responsibility of morphologists, whatever object, living or fossil, they may deal with, to study such features, evaluate them, and apply them for systematic work.

There is little reason to doubt the reliability of the morphological evidence. The occurrence in Jurassic deposits of abundant gastropods whose present-day relatives are herbivorous will indeed suggest the presence of a rich growth of aquatic vegetation in Jurassic times. The presence of species of *Ancylus* or its related genus in a Miocene bed will certainly suggest the presence of diatoms. There is no reason to doubt that species of *Lymnaea*, if they are as they seem, true *Lymnaea*, existed in early Cretaceous times under much the same kind of environmental conditions as they do today. We are accumulating such fossil data

by collecting them in the light of the known ecological criteria.

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OCEAN-BOTTOM PHOTOGRAPHS OF THE NERITIC AND BATHYAL ENVIRONMENT SOUTH OF CAPE COD, MASSACHUSETTS

BY JOHN NORTHROP

ABSTRACT

Ocean-bottom photographs and core samples, taken south of Cape Cod along a profile normal to the bathymetric contours, show definite changes in bottom markings, benthonic forms, and sediments. The different types of environment indicate a division into five major zones for which typical bottom photographs are presented.

CONTENTS

TEXT

	Page
Abstract	1381
Introduction	1381
Previous work	1381
Description of zones	1381
Zone 1	1381
Zone 2	1382
Zone 3	1382
Zone 4	1382
Zone 5	1382
Summary	1383
References cited	1383

ILLUSTRATIONS

Plate	Facing page
1. Ocean-bottom photographs	1382
2. Ocean-bottom photographs	1383
3. Location of stations	1384

INTRODUCTION

The Ewing under-water camera (Ewing *et al.*, 1946a), modified to obtain a short core simultaneously with the bottom photograph, was used. The first traverse consisted of 53 bottom stations spaced about 2 miles apart (Pl. 3). Acknowledgment is made to the officers and crew of the Research Vessel BALANUS and to the Woods Hole Oceanographic Institution; to B. C. Heezen and J. I. Ewing who worked with the author in obtaining the data; to W. M. Ewing and J. L. Worzel who directed the program; to G. P. Woollard and H. C. Stetson for their valuable advice; and to the Bureau of Ships, U. S. Navy, through which this work was made possible.[1]

PREVIOUS WORK

Ocean-bottom photographs of marine sedimentary conditions have been made by Ewing *et al.* (1946a; 1946b), Shepard and Emery (1946), Shepard (1949), and by Northrop and Heezen (1951). Mechanical analysis of sediments was made by the combination wet-sieve and pipette method described by Stetson (1938), to which sodium oxylate was added to deflocculate the finer fraction. Median and quartile measurements were taken from the cumulative frequency curves, and values were calculated for skewness and sorting index (Krumbein and Pettijohn, 1938).

DESCRIPTION OF ZONES

Zone 1

The near-shore end of the traverse is an area of reworked gravel, from which the finer material had been washed away by wave and current action. Figure 1 of Plate 1 shows that the remaining rock fragments are poorly sorted and well rounded, but their large size prevented recovery of any samples. This zone persists 35

[1] Work done under U. S. Navy contract NOBsr 39092.

miles out to sea into water 80 meters deep and is probably made up of glacial moraine.

Zone 2

This narrow zone of silts and sands extends from 35 to 45 miles off shore in 80–90 meters of water. The bottom was so compact that the coring tube penetrated only the top 5 cm of sediment which shows a good sorting index of 1.2–2.0. Figure 2 of Plate 1 shows that this zone has competent transporting currents as the shells are overturned and partly covered with sediment. Other photographs in this zone show other shells concave upward and partly filled with sediment. The attitude of the shells does not indicate current action in itself, as numerous starfish shown in the photograph undoubtedly disturb the shells. The relatively hard bottom, good sorting, and presence of sediment in the shells indicate winnowing action and movement of sediment over the bottom.

Zone 3

This is a wide zone of soft mud from 45 to 75 miles off shore out to the 100-meter bathymetric contour. In this zone the median slips from .15 mm to .05 mm, the material contains 70–80 per cent silt, is better sorted at the surface, but the mode lies on the coarse side of the median partly because of the abundant shell fragments shown in the photograph. The surface layer is coarser, with the fines winnowed out, and a contemporaneous unconformity is in the making. Typical photographs of the mud zone show large shell fragments on a muddy bottom that has been stirred up by the coring tube in addition to numerous pock marks and a burrowing of about a 6-inch radius. The starfish, so abundant in adjoining zones, are absent as is the criss-cross pattern of trails; the latter may be obscured by movement of silt along the bottom.

Zone 4

This extraordinary zone crowns the break in slope from 75–85 miles off shore in 110–200 meters of water. The median rises to .16 mm, the sorting averages 1.5, the skewness approaches unity, and the amount of silt falls to 20 per cent. The material is so well compacted that the coring tube penetrated only a few centimeters. Bottom photographs in this zone (Pl. 2, fig. 1) show its pock-marked character with numerous starfish and shell fragments, but no ripple marks. This bears out Stetson's suggestion (1934) that the material was laid down as an eolian deposit at a time of lower sea level and not by present-day currents sweeping around Cape Cod (Alexander, 1934). The lack of material above the sand indicates nondeposition in the area since the rise in sea level.

Zone 5

The seaward end of the traverse continues down the continental slope into 200–800 meters of water 85–110 miles off shore. The median falls off sharply to .05 mm, the sorting ranges from 1.5 to 4.5, and the mode climbs to the fine side of the median as the amount of silt rises to 90 per cent. The material in each sample is quite distinctive; sometimes the surface silt is better sorted than the subsurface, and sometimes not so well sorted. This is taken as further evidence of mixing and slumping down slope, similar to that described in near-by areas (Phleger and Hamilton, 1946; Stetson, 1949; Northrop and Heezen, 1951). Figure 2 of Plate 2 shows a distinct hummocky type of bottom so characteristic of landslide areas. In addition it shows that sea anemonies are the most abundant form of life. It also shows numerous elongate gouges on the bottom, thought to have been formed by fish which have brushed against the bottom.

PLATE 1.—OCEAN-BOTTOM PHOTOGRAPHS

FIGURE 1.—IN 25 METERS OF WATER, SHOWING HARD GRAVEL BOTTOM AND ROUNDED ROCK FRAGMENTS
Station D-2; Latitude 41°12′ N.; Longitude 70° 59′ W.; flash bulb #5; camera to light 43″, camera to bottom 77″, focus 4.5′; stop f.9, shutter speed 1/25 sec.

FIGURE 2.—IN ZONE 2 SHOWING STAR FISH, SHELL FRAGMENTS, AND GRANULAR-APPEARING BOTTOM IN 40 METERS OF WATER
Station D-7; Latitude 40°48′ N.; Longitude 70°56′ W.; camera setting same as Figure 1.

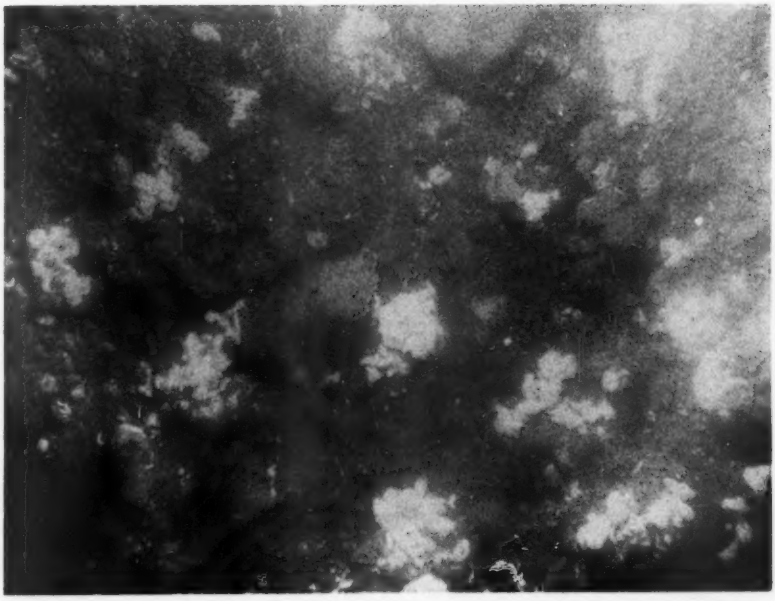

FIGURE 1

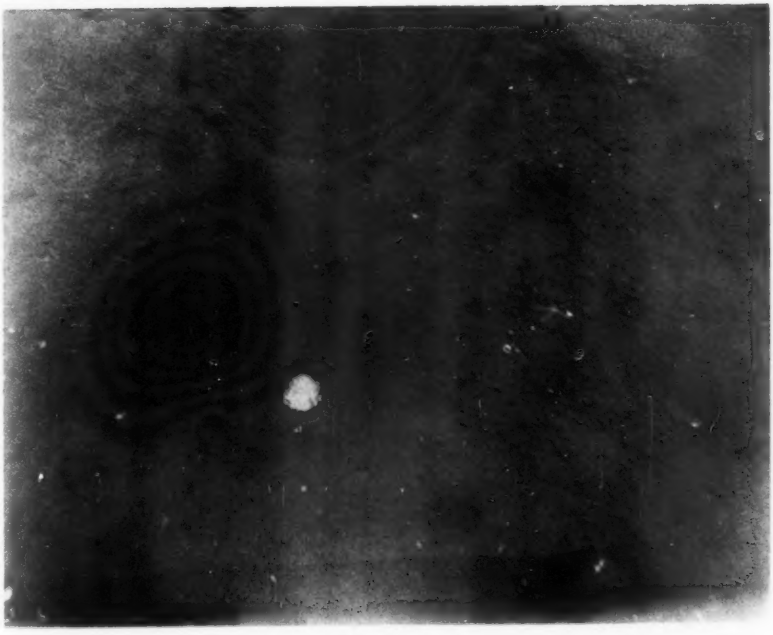

FIGURE 2

OCEAN-BOTTOM PHOTOGRAPHS

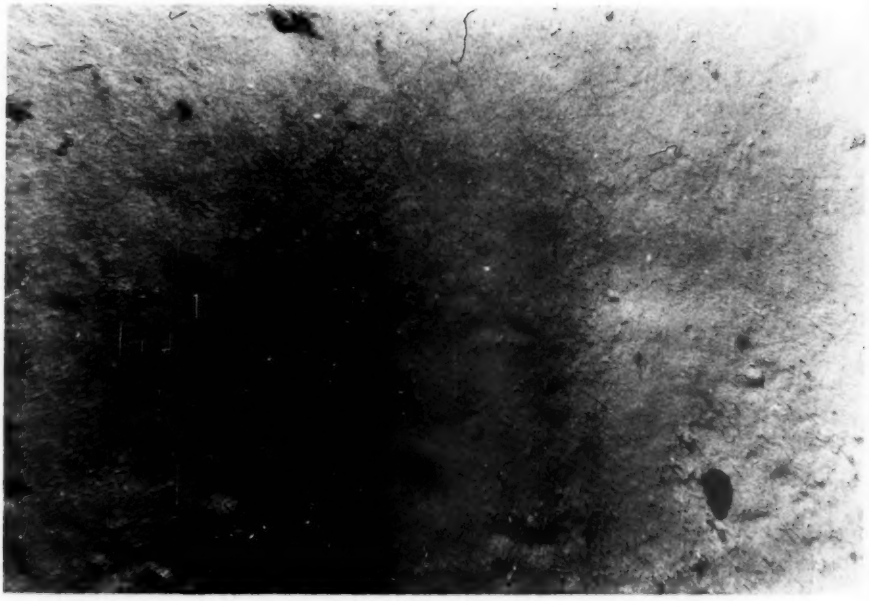

FIGURE 1

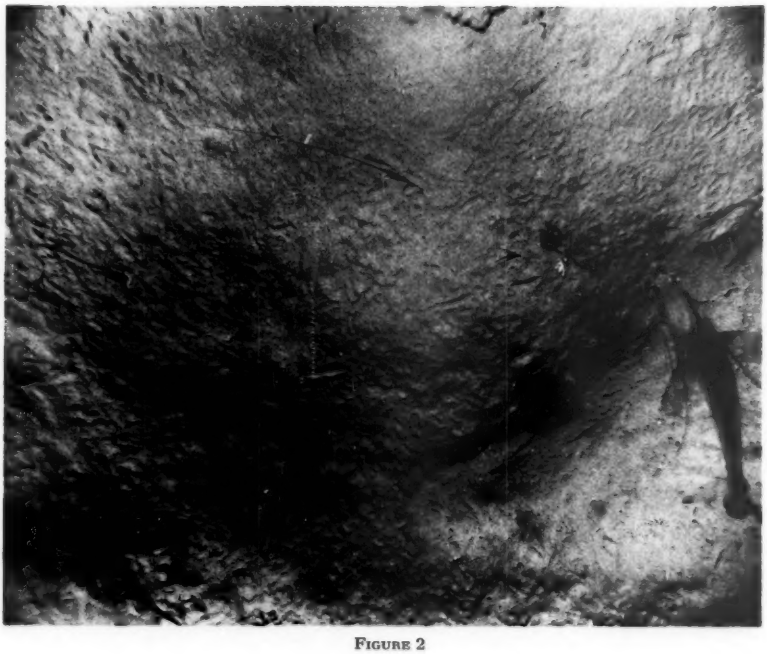

FIGURE 2

OCEAN-BOTTOM PHOTOGRAPHS

Summary

Both the neritic and bathyal districts are areas of nondeposition; the former is an area of winnowing action, and the latter an area of landslides and slumping. The material being reworked is residual from a former period, and the life supported in the various zones seems to be controlled by the type of sediment in addition to depth of water. Geologists can use features photographed on the bottom in determining the sedimentary environment of rock facies in which such phenomena are preserved.

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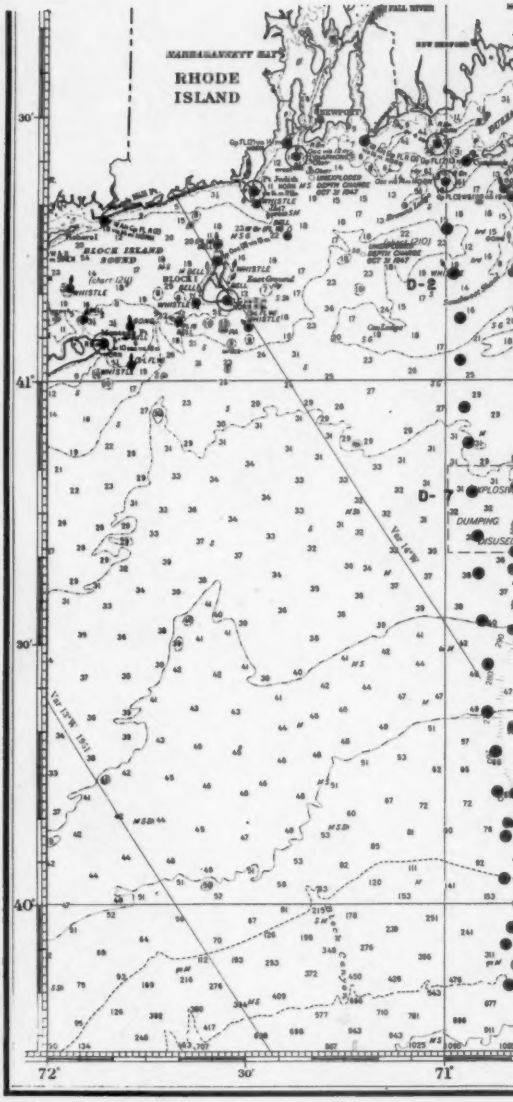
Contribution No. 36, Lamont Geological Observatory

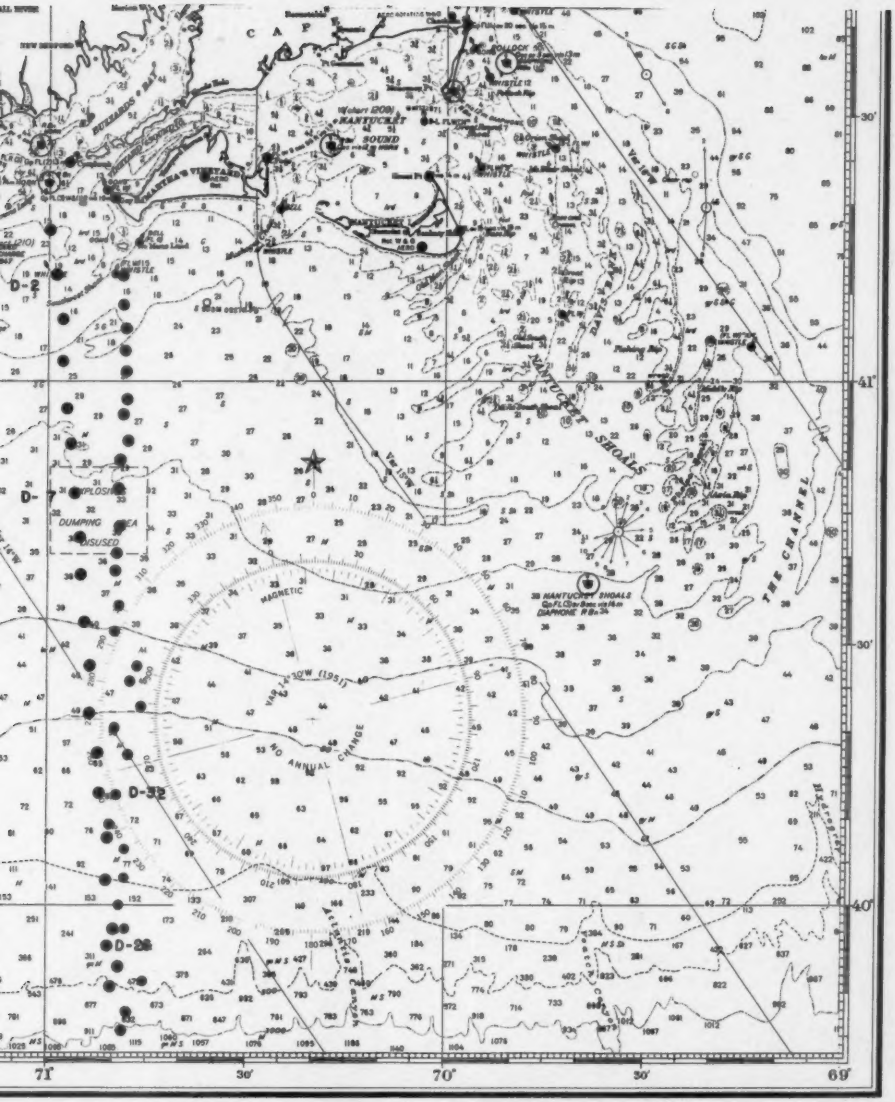
Plate 2.—Ocean-Bottom Photographs

Figure 1.—In Zone 4 Showing Pock Marks and Absence of Ripple Marks 110 Meters of Water Station D-32; Latitude 40°13′N.; Longitude 70°50′ W.; camera setting same as in Plate 1.

Figure 2.—In Zone 5 Showing Gouges in Bottom and Animal Life in 700 Meters of Water Station D-26; Latitude 39°55′ N.; Longitude 70°51′ W.; camera setting same as in Plate 1.



Note: Please substitute this map for the map printed in the paper by John Northrop (December 1951 Bull., Pt. 3, facing p. 1383). In printing, the southern portion of the map was omitted.



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SOUNDINGS IN FATHOMS

70

LOCATION OF STATIONS

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DEFORMATION OF YULE MARBLE: PART IV—EFFECTS AT 150°C.

BY DAVID GRIGGS, FRANCIS J. TURNER, IRIS BORG, AND JOHN SOSOKA

ABSTRACT

Yule marble has been experimentally deformed at 150°C under conditions otherwise identical with those at room temperature reported in Part I. The strength is lowered about 40 per cent by this increase in temperature, and the relative ease of translation versus twinning on $\{01\bar{1}2\}$ is increased. Fabric measurements on the deformed material show trends nearly identical with those at room temperature (Part III). The individual grains are more homogeneously deformed, and, perhaps as a consequence, the fabric changes appear to be somewhat more sharply defined. Effects of interstitial water and of slow rate of deformation are negligible except for a lowering of strength similar to that observed at room temperature. The fabric changes are completely consistent with those predicted in Part II under the hypothesis of homogeneous deformation. By all tests applied, the mechanism of deformation is thus the same as at room temperature, and is dominantly twinning and translation on $\{01\bar{1}2\}$. The observed lowering in strength and greater homogeneity of texture suggest an approach to conditions of natural deformation.

CONTENTS

TEXT

	Page
Introduction	1385
Acknowledgments	1386
Experiments	1386
Apparatus	1386
Procedure	1386
Results	1387
Miscellaneous effects	1392
Summary of experimental results	1393
Fabric of deformed marble	1393
Material for study	1393
General microscopic character of fabric	1393
Petrofabric analysis	1395
Procedure	1395
Preferred orientation of optic axis c	1395
Preferred orientation of best developed $\{01\bar{1}2\}$ lamellae	1398
Preferred orientation of edges $[e{:}e]$	1398
Influence of temperature, water, time on deformed fabric	1404
Temperature	1404
Water	1404
Time	1404
Conclusion	1404
References cited	1405

ILLUSTRATIONS

Figure	Page
1. Stress-strain curves of Yule marble	1388
2. Stress-strain curves of calcite single crystals	1389
3. Effect of varying amounts of water	1390
4. Effect of different rates of strain	1391
5. Acutely intersecting lamellae e_1 and e_1' in a calcite grain	1394
6. Orientation diagrams for c axes of calcite in undeformed Yule marble	1396
7. Orientation diagrams for c axes of calcite in deformed Yule marble	1397
8. Pairs of c axes for twinned grains of calcite	1398
9. Orientation diagrams for best-developed $\{01\bar{1}2\}$ lamellae in calcite of deformed Yule marble	1399
10. Orientation diagrams for edges $[e{:}e]$ in calcite of deformed Yule marble	1400
11. Idealized orientation diagrams showing maxima for c axes, $\{01\bar{1}2\}$ lamellae, and $[e{:}e]$ edges, in relation to applied stress and pre-deformational fabric	1401
12. Comparison of fabrics of marbles deformed dry and in water at 150°C	1402
13. Comparison of fabrics of marbles deformed rapidly and slowly at 150°C in water	1403

TABLES

Table	Page
1. Test of homogeneous hypothesis on 150°C dry data	1389
2. Test of homogeneous hypothesis on 150°C wet data	1391
3. Effect of confining pressure on stress-strain characteristics	1392
4. Specimens subjected to fabric analysis	1393

INTRODUCTION

Parts I, II, and III of this paper (Griggs and Miller, 1951; Handin and Griggs, 1951; Turner and Ch'ih, 1951) described the physical properties and fabric changes in Yule marble deformed dry, at room temperature, under 10,000 atmospheres confining pressure. Tay-

lor's hypothesis of homogeneous deformation was shown to be consistent with the observations. The high stresses, low temperature, and unnatural texture of the deformed material made it seem unlikely that these observations and this hypothesis would apply to naturally deformed marble. Accordingly, additional studies are being made in an attempt to approach more nearly the natural environment and phenomena. This paper reports the first step—an increase of temperature to 150°C, and the addition of interstitial water. All other conditions remain the same.

Acknowledgments

The experimentation was supported by a grant from the Office of Naval Research. The fabric studies were made possible by a grant from the Penrose Bequest of The Geological Society of America. Some of the pressure apparatus and the temperature-control equipment was built with the assistance of several grants from The Geological Society of America. Apparatus on loan from Harvard University and the U. S. Geological Survey was essential. The excellent craftsmanship of Mr. Fred Banning and Mr. Edwin Perry in the Institute of Geophysics Shop was indispensable. Mr. John de Grossé prepared his usual excellent thin sections. The Yule marble was provided by Mrs. E. B. Knopf out of whose inspiration this program has grown.

Experiments

Apparatus

The apparatus used in these experiments is identical in principle and similar in design to that described in Part I. The high-pressure cylinder containing the specimen is heated by an external furnace, and is designed to minimize temperature gradients insofar as practicable. The temperature is controlled by a thyratron regulator, using a separate resistance winding as a sensing unit. The temperature of the cylinder is measured by a thermocouple deep in the cylinder wall. The difference between the cylinder temperature and the specimen temperature was determined in a mock-up at low pressure, with a second thermocouple in the place normally occupied by the specimen, and with all the rest of the apparatus the same. This difference is 8°C at 150°C, 15°C at 300°C. During a run the cylinder temperature varies less than 1°C on the average.

The specimen assembly is identical to that described in Part I. Pressure, force, friction, and piston displacement are measured, calibrated, and reduced as described in Part I. Experimental accuracies are about the same, but the reproducibility of the stress-strain curves is not so good. The average deviation from the mean is about 5 per cent as compared to 3 per cent in Part I. This is supposed to be due to the greater importance of undetermined variations in friction on these weaker specimens.

Procedure

The assembly is first brought to the operating pressure, then heated. Two hours is required for the cylinder to come to thermal equilibrium. The test run is then made as described in Part I, either in extension or compression. The pressure is then reduced and the furnace turned off. Cooling takes about 2 hours. The whole run thus takes about four times as long as a room-temperature test.

For tests with interstitial water, the copper jacket is soldered to the two end pieces (*see* Part I, Fig. 2) leaving a small vent hole. The assembly is then filled with water (or other fluid) under vacuum, and the vent soldered shut. Since some water boils off while the vent is being soldered, there is no means of determining the exact amount of water before an experiment. After an experiment the specimen is removed from its jacket and weighed immediately. It is then heated to 150°C for 3 hours to evaporate the water, and weighed again. The difference in weight is taken to be the weight of the interstitial water present. Subsequent heating for longer periods showed no further change in weight.

Since the amount of water present, and hence its pressure under the test conditions, cannot be accurately determined in advance, it is generally impossible to perform extension tests with water present. When the water pressure exceeds the difference between the confining pressure and the longitudinal stress, the end

pieces separate from the specimen, and the experiment is terminated. Only one experiment in extension was successful, and, since the jacket ruptured after 13 per cent deformation in this case, the amount of water present could not be determined.

Experiments with interstitial water in compression present no new problems.

During these experiments, a cylinder packing failed, and further experiments had to be restricted to 5000 atmospheres confining pressure. Several comparison runs were made at 5000 atmospheres confining pressure to determine the effect of this single environmental variable at room temperature, 150°C, dry, and with water.

With the exception of the single long-time test, all experiments were performed at the same rate of strain as those in Part I. All Yule marble specimens were cut from the same block as those of Part I.

Results

Figure 1, B shows the average stress-strain curves for Yule marble, dry, at 150°C and 10,000 atmospheres confining pressure. These are to be compared with the similar room-temperature curves (Fig. 1, A) reproduced from Part I. Two things are immediately apparent: (1) the specimens are all considerably weaker at 150°C; (2) the relative strengths in the four orientations are different at 150°C.

These differences suggested that the mechanism of deformation inferred from room-temperature data (Parts I, II, III) might no longer apply. To check this, the method used in Part I, based on analytical data from part II, was tested for its ability to correlate the relative strengths at a given average shear strain (0.1). The results are shown in Table 1. (*See* Part I, p. 860–861, for explanation of method.)

The standard deviation of the calculated from the observed values is 6.1 per cent. The standard deviation of the observed values from their mean is 12.5 per cent. Thus, the degree of correlation obtained is not nearly so good as that at room temperature (Part I, p. 861), and the deviation is considered to be greater than the experimental error. However, the degree of correlation obtained indicates strongly that the mechanism of deformation is basically similar to that at room temperature.

The values of the derived parameters as compared to those at room temperature are:

	Room Temperature	*150°C*
τ_a	840 kg/cm²	575 kg/cm²
τ_b	1470 kg/cm²	810 kg/cm²
$\alpha = \tau_b/\tau_a$	1.75	1.41

where τ_a is the hypothetical average resolved shear stress on those $\{01\bar{1}2\}$ planes with maximum resolved shear stress, in the twinning sense, and τ_b that in the translation sense, as explained in Part I. It is worthy of emphasis that, under the assumptions employed, these are not real shear stresses since resistance to deformation occurs not only on the $\{01\bar{1}2\}$ planes employed in this analysis, but also on others. Nevertheless, it is felt that the differences in these values at room temperature and at 150°C are qualitatively related to the actual difference in the response of the individual crystal grains of the aggregate. This would imply that the shear stress necessary to produce twinning is only slightly reduced by the increased temperature, while the shear stress required to produce translation is reduced much more.

The behavior of single crystals substantiates this deduction. Figure 2 shows preliminary stress-strain curves of calcite single crystals at room temperature and at 150°C in two orientations in each case. Those compressed parallel to the c axis are oriented so that twinning on $\{01\bar{1}2\}$ is impossible, and translation is favored. Those compressed normal to the c axis are favorably oriented for twinning on one $\{01\bar{1}2\}$ plane, and this is observed to be the predominant mechanism of deformation. The shear stress for twinning is the same at both temperatures within the experimental error at these low stresses. The shear stress in those favorably oriented for translation is reduced three to four times by the increase in temperature. These results are tentative, owing to the difficulty of preparing single crystal specimens without flaws. The heating involved in soldering on the jacket induces some r cleavage, due to thermal shock, and the effect of this on the mechanical properties is not known. Experiments to refine these data are planned with jackets which require no heat. This greater

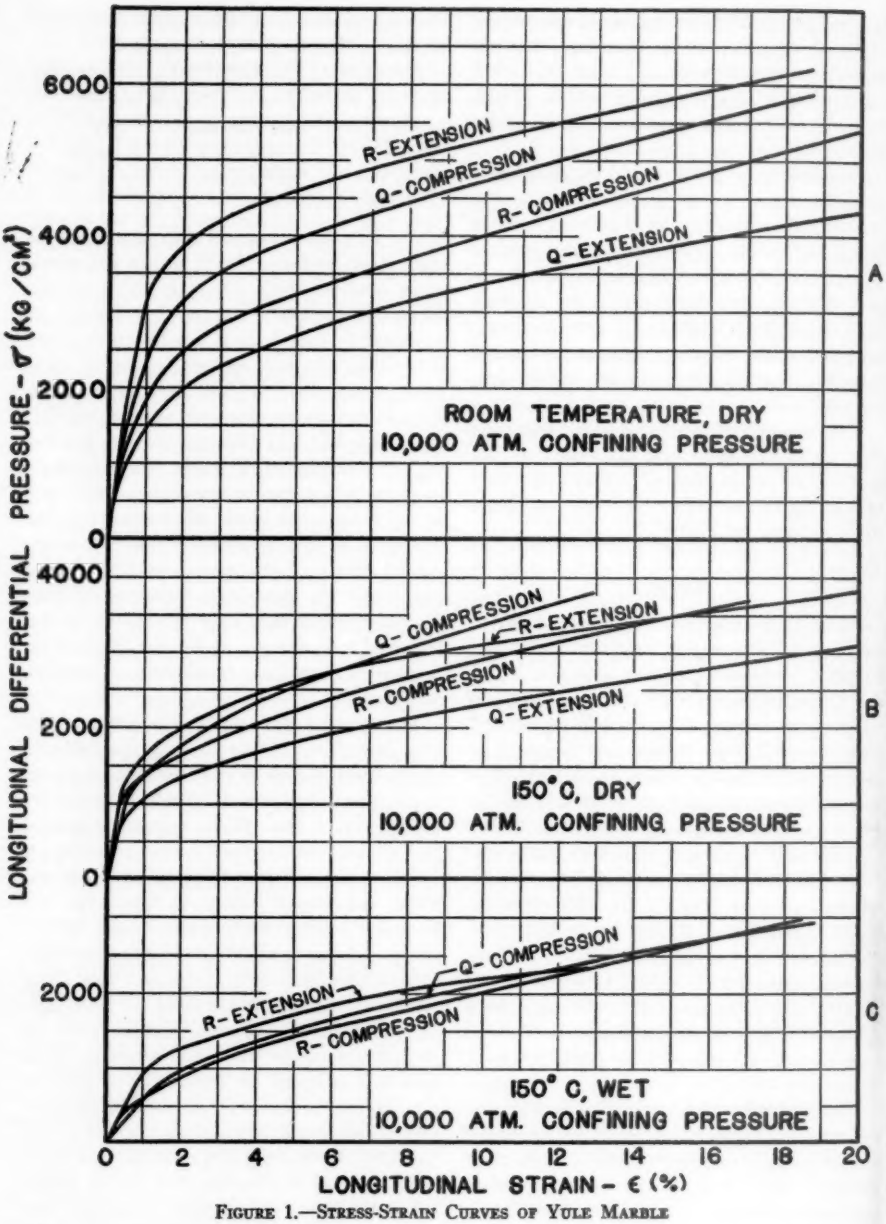

FIGURE 1.—STRESS-STRAIN CURVES OF YULE MARBLE

effect on translation than on twinning is, however, consistent with the interpretation of the marble data.

The effect of water on stress-strain relations is shown in Figure 1, C. The amount of water in the *R* cylinder in extension is unknown, since

TABLE 1.—TEST OF HOMOGENEOUS HYPOTHESIS FOR INTERNAL CONSISTENCY ON 150°C, DRY, DATA

Orientation	Strain for $s = .1$ per cent	σ_{obs}	F_a	F_b	$F_a + 1.41 F_b$	σ_{calc}	$\frac{\sigma_{calc}}{\sigma_{obs}}$
Q—Comp.	3.68	2250	.72	2.00	3.54	2030	.91
Q—Ext.	3.77	1680	2.20	.45	2.83	1620	.96
R—Comp.	3.10	1880	2.96	.27	3.34	1920	1.02
R—Ext.	3.01	2320	.64	2.68	4.42	2540	1.09
d—Ext.	3.08	2100	2.13	1.11	3.70	2120	1.01

by Griffiths (1937) to be 0.45 per cent. Since 0.52 per cent is the maximum achieved in these experiments, it would appear that the porosity is not sensibly increased under the conditions of our tests. Figure 3 shows the effect on the stress-strain curves of varying amounts of water, all other conditions remaining the same.

It had previously been reported (Griggs, 1940; Knopf, 1949) that at 150°C, in the presence of commercial carbonated water, the stress-strain curve was grossly different from

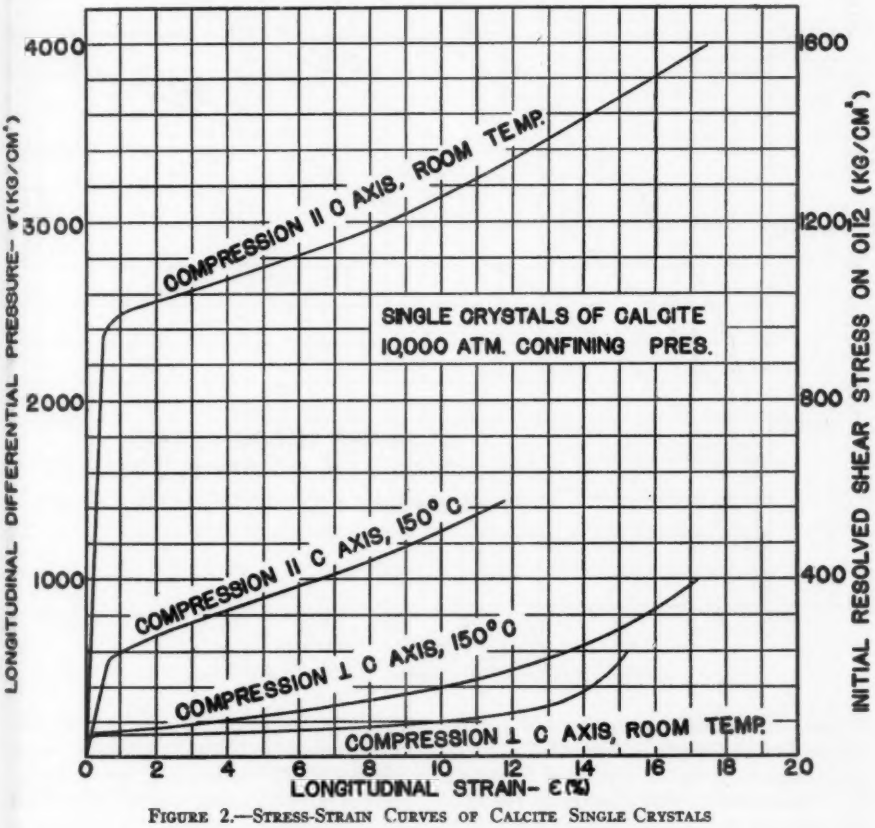

FIGURE 2.—STRESS-STRAIN CURVES OF CALCITE SINGLE CRYSTALS

the jacket broke, terminating the run. The *R* cylinder in compression had 0.49 per cent water, and the *Q* cylinder in compression had 0.52 per cent water, measured as described above. The normal porosity of Yule marble is reported that for marble deformed at room temperature (Knopf, 1949, Fig. 48) and that the texture of the deformed marble was also strikingly different (Knopf, 1949, Pl. 11). Present experiments with commercial carbonated water failed

to produce either of these effects. The early stress-strain curve was known to be of doubtful accuracy because of the primitive nature of the apparatus then used, and this could possibly account for the difference observed. The apparent difference in texture previously recorded is not understood. It may possibly be explained by the fact that the orientation of the early specimens and section were in doubt, and it has since been learned that the texture of highly deformed Yule marble varies considerably with variations of the initial orientation. As shown in Figure 3, the carbonated water has approximately the same effect on the stress-strain curves as the same amount of distilled water would have. Cursory microscopic examination showed no peculiarities of those specimens impregnated with carbonated water.

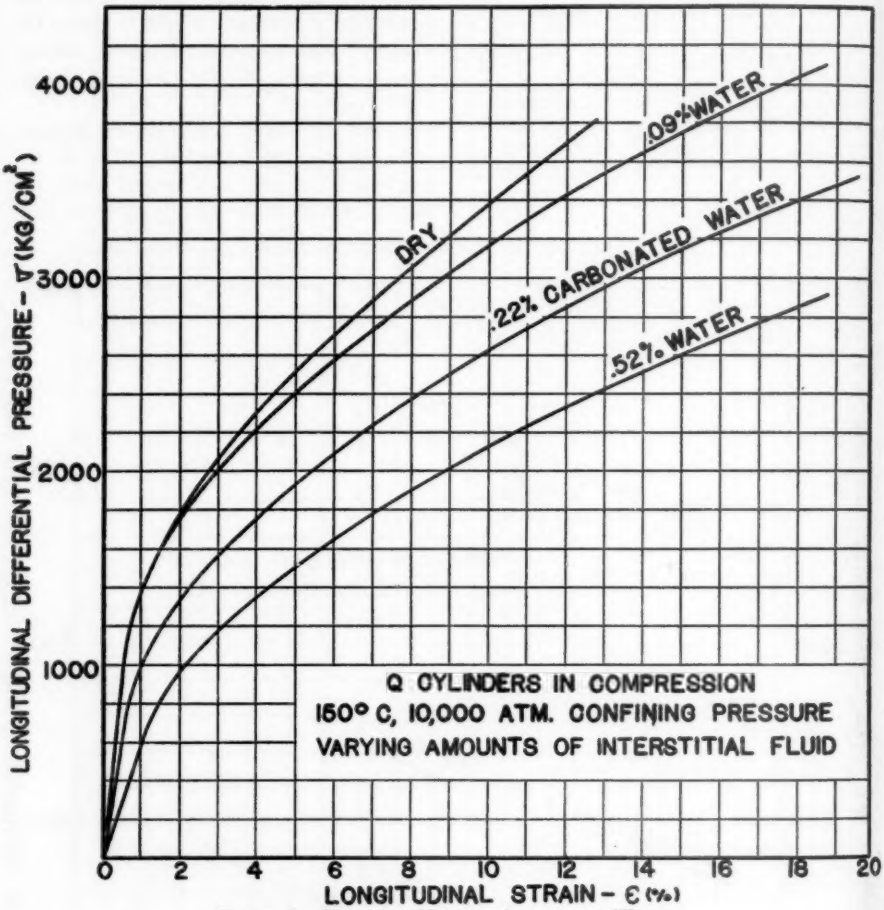

FIGURE 3.—EFFECT OF VARYING AMOUNTS OF WATER

It was initially thought that the pronounced effect of water on strength of the Yule marble was due to recrystallization. To test this, an experiment with water was done at room temperature, where any recrystallization would be expected to be small. The strength in this experiment was reduced proportionately to the same degree as with water at 150°C. Conse-

TABLE 2.—TEST OF HOMOGENEOUS HYPOTHESIS FOR INTERNAL CONSISTENCY ON 150°C, WET, DATA

Orientation	σ_{obs}	F_a	F_b	$F_a + 1.50F_b$	σ_{calc}	$\frac{\sigma_{calc}}{\sigma_{obs}}$
Q—Comp	1300	.72	2.00	3.70	1230	.95
R—Comp	1120	2.96	.27	3.36	1120	1.00
R—Tension	1480	.64	2.68	4.63	1540	1.04

Standard deviation σ_{calc} from σ_{obs} = 4.4%
τ_a = 330 kg/cm²
τ_b = 500 kg/cm²
$\tau_a/\tau_b = \alpha = 1.50$

the specimens concerned is unknown. Nevertheless, this constitutes some additional confirmation that the mechanism of deformation is not changed by the presence of water.

The effect of rate of loading was tested crudely in one experiment, illustrated in Figure 4. The stress was raised to 1530 kg/cm² at the normal rate of strain and then maintained nearly constant for 20 minutes (A to B). During this time the rate of strain decreased exponentially with time, indicating elastic flow. The stress was then raised (B to C) at

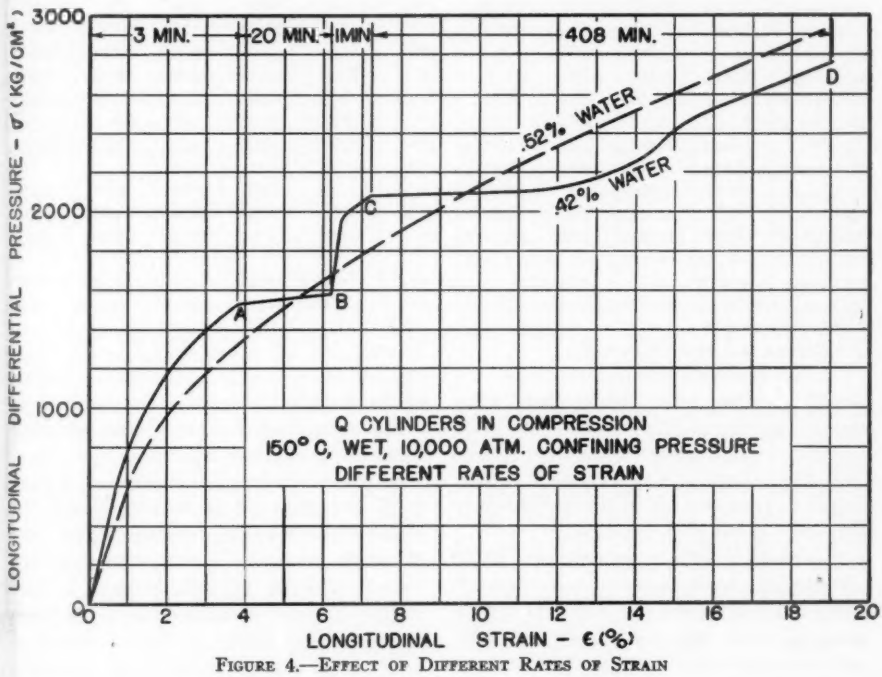

FIGURE 4.—EFFECT OF DIFFERENT RATES OF STRAIN

quently the effect of the water is now thought to be mainly mechanical. The difference between jacketed and unjacketed specimens in kerosene (Griggs, 1936, p. 567) is similar.

A test of the homogeneous deformation hypothesis on the three stress-strain curves of Figure 1, C yields the result shown in Table 2.

Too much weight should not be attached to this correlation, since there are only three observations, and the water content of one of

the normal rate of strain to 2080 kg/cm². It was then intended to keep the stress constant, but, because of apparatus difficulties, the stress gradually increased over a period of nearly 7 hours to 2760 kg/cm² (point D). The strain-time curve is not decipherable because of this complicated stress history, but there is no indication of anything but elastic flow. This experiment was intended to explore the possibilities of obtaining recrystallization at

150°C in the presence of water. All the evidence from the stress-strain-time history is negative. The fabric evidence will be discussed later. For comparison, the stress-strain curve of a similar specimen with slightly more water tested at the normal rate of strain (duration 14 minutes) is superimposed on Figure 4 (dashed line). The 7-hour test is seen to be only slightly different, consistent with the interpretation that only elastic flow occurred.

The effect of 5000 atmospheres vs. 10,000 atmospheres confining pressure is shown in Table 3, for dry specimens in several orientations, at room temperature and at 150°C. As reported before (Griggs, 1936; Balsley, 1941), the principal effect of 10,000 vs. 5000 atmosphere confining pressure is to increase the ductility. For example, an *R* cylinder may be stretched more than 20 per cent at 10,000 atmospheres with no signs of rupture, while at 5200 atmospheres rupture occurred at 13.6 per cent extension. A *Q* cylinder at 5200 atmospheres, however, showed no sign of rupture at 20 per cent extension. The difference between the two orientations is probably due to the fact that *Q* is oriented favorably for twinning while *R* is not. At 10,000 atmospheres, a *Q* cylinder has been stretched 45 per cent. Since the mean stress is probably a more significant parameter than the pressure of the confining fluid, values for mean stress are given in Table 3. The mean stress varied from 3770 to 12,260 kg/cm².

TABLE 3.—EFFECT OF CONFINING PRESSURE ON STRESS-STRAIN CHARACTERISTICS

Orientation	Temperature	Confining pressure σ_2 (Atm.)	At 3% Strain		At 6% Strain		At 12% Strain		At 18% Strain	
			Longitudinal stress $\sigma_1 - \sigma_2$ (kg/cm²)	Mean stress $\frac{\sigma_1 + \sigma_2 + \sigma_3}{3}$ (kg/cm²)	Longitudinal stress $\sigma_1 - \sigma_2$ (kg/cm²)	Mean stress $\frac{\sigma_1 + \sigma_2 + \sigma_3}{3}$ (kg/cm²)	Longitudinal stress $\sigma_1 - \sigma_2$ (kg/cm²)	Mean stress $\frac{\sigma_1 + \sigma_2 + \sigma_3}{3}$ (kg/cm²)	Longitudinal stress $\sigma_1 - \sigma_2$ (kg/cm²)	Mean stress $\frac{\sigma_1 + \sigma_2 + \sigma_3}{3}$ (kg/cm²)
Q—Comp	Room	4,900	3550	6250	4150	6450	4900	6700	5380	6860
Q—Comp	Room	10,000	3520	11500	4140	11710	5020	12000	5800	12260
Q—Ext	Room	5,200	1950	4720	2480	4550	3130	4330	3630	4160
Q—Ext	Room	10,000	2280	9570	2860	9380	3580	9140	4170	8940
R—Comp	Room	5,000	2610	6040	3220	6240	3950	6480	4510	6670
R—Comp	Room	10,000	2820	11300	3390	11500	4320	11770	5150	12050
R—Ext	Room	5,200	3950	4060	4340	3930	4600*	3840	Broke	—
R—Ext	Room	10,000	4200	8930	4750	8750	5510	8500	6140	8290
R—Comp	150°C	5,200	2050	6060	2600	6240	3290	6470	—	—
R—Comp	150°C	10,000	1850	10950	2370	11120	3140	11380	3690	11560
R—Ext	150°C	5,000	2350	4380	2950	4180	3720	3930	4180†	3770
R—Ext	150°C	10,000	2240	9590	2750	9420	3250	9250	3700	9100
Av. ratio 5,000/10,000:			.973		.974		.950		.940	

* Incipient rupture.

† Extrapolated from 16% strain.

In general, the longitudinal stress at a given strain is slightly less at 5000 than at 10,000 atmospheres confining pressure, and this difference increases for higher strains. The average values of the ratio of stress at 5000 to that at 10,000 atmospheres are given below the appropriate columns in Table 3. A notable exception is that all measurements at 150°C give higher stresses at 5000 than at 10,000 atmospheres. No explanation is offered for this.

Miscellaneous Effects

A specimen of Westerley granite was tested in compression at 150°C, wet, at 10,000 atmospheres confining pressure. A longitudinal stress of 6300 kg/cm² was applied. The stress-strain curve indicated some plastic flow. On disassembly, however, it was found that the

steel end pieces had deformed. No residual deformation was measured on the granite specimen. It is concluded that under these environmental conditions granite is not appreciably plastic.

In one extension test at 150°C with water, the marble specimen separated in the middle. On disassembly, it was found that dendritic growths of native copper completely covered the fractured face. No particular importance was attached to this since the environment was unknown. The pressure fluid—benzine—leaked in at some stage of the proceedings after the rupture of the marble. Some small euhedral calcite crystals were found deposited on the *outside* of the jacket.

In all cases, the grains of the marble deformed the steel cups with which they were in contact. The steel retains a perfect replica of the deformed surface of the marble.

Summary of Experimental Results

The principal effect of increasing the temperature from room temperature to 150°C is to decrease the strength of marble by an amount averaging about 40 per cent. This lowering of strength varies for the different orientations in such a way as to imply that resistance to translation on $\{01\bar{1}2\}$ is decreased more than is resistance to twinning. This is qualitatively confirmed by preliminary single-crystal experiments. The hypothesis of homogeneous deformation by translation and twinning on $\{01\bar{1}2\}$ presented in Parts I, II, III has now been tested by the same procedures on the 150°C data and is found consistent with observations.

No evidence for recrystallization flow was observed. The presence of water diminished the strength at 150°C in the same proportion as at room temperature. A test of 7 hours duration in water disclosed no evidence of psuedoviscous flow as would be expected if recrystallization were occurring.

The evidence from the physical measurements thus indicates that the mechanism of deformation at 150°C, both dry and in the presence of water, is similar to that previously suggested (Parts I, II, and III) for deformation at room temperature.

Fabric of Deformed Marble

Material for Study

The material used for study of fabrics developed by deformation at 150°C consists of sections cut from seven deformed cylinders (Table 4).

Table 4.—Specimens Subjected to Fabric Analysis†

Cylinder number	Cylinder axis*	Type of deformation	Per cent strain	Conditions of experiment
306	T (R)	Compression	18	Dry
321	T (R)	Compression	20	0.49% water
255	3 (Q)	Compression	19	0.52% water
260	3 (Q)	Compression	19	0.42% water; slow test
176	T (R)	Extension	12	In water
252	3 (Q)	Extension	20	Dry
287	*d*	Extension	20	Dry

* Probable correlation with *P*, *Q*, and *R* cylinders of an earlier series of experiments (Griggs, 1940; Knopf, 1949) is noted in brackets (*cf.* Part III, p. 888).

† All specimens deformed at 10,000 atm. confining pressure.

General Microscopic Character of Fabric

The fabric of these Yule marble specimens deformed at 150°C is generally very similar to that of specimens of the same orientation deformed a like amount at room temperature. Intragranular deformation, principally made evident by the profuse development of $\{01\bar{1}2\}$ lamellae, is predominant in this material, as in that deformed at room temperature. The degree of development of lamellae is not significantly different from that in corresponding specimens deformed at room temperature. The most conspicuous difference in the thin sections is that the grains in the 150°C material are not separated as much as in the room-temperature material. In the latter, regardless of the care taken in impregnation and cutting of the thin sections, grains are commonly separated at the grain boundaries, whereas, in the 150°C material, the grain boundaries are usually sharp and well defined with no evidence of separation of adjacent grains. This is perhaps correlated with the coherence of the material after re-

moval from the pressure chamber. Specimens deformed 20 per cent at room temperature are weak, can be broken between the fingers, and are friable at fractured surfaces. The 150°C specimens are apparently much stronger.

The next most obvious difference is that the lamellae are less distorted in the 150°C specimens. Local bending of lamellae at grain contacts and within the grains is considerably less evident in the 150°C specimens than in corresponding room-temperature specimens. This has an important consequence for the purposes of our study—the optical properties of highly deformed grains are much more easily determined on the universal stage as a result of the greater uniformity within the grains. In contrast to our previous experience with marble deformed at room temperature, cylinders of any orientation elongated or shortened by as much as 20 per cent at 150°C were found satisfactory for petrofabric analysis.

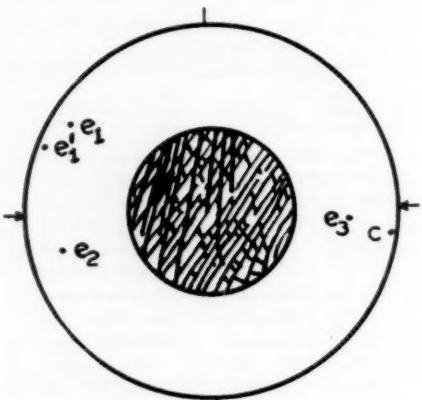

FIGURE 5.—ACUTELY INTERSECTING LAMELLAE e_1 AND e_1' IN A CALCITE GRAIN

Specimen 260. Continuous lines sloping down from right to left are traces of e_1. Heavier nearly vertical lines at left are e_1'. Discontinuous lines are e_2. Poles of e_1, e_1', e_2, and e_3 are shown in projection.

As in the case of deformation at room temperature, where orientation of cylinders in the stress field favors twinning on $\{01\bar{1}2\}$—*T* (*R*) cylinders in compression or *3* (*Q*) cylinders in extension—lamellar twinning on $\{01\bar{1}2\}$ is microscopically obvious in many grains; where the cylinder is unfavorably oriented for twinning, the majority of $\{01\bar{1}2\}$ lamellae appear as sharp lines with no obvious indication of twinned origin. In microsections cut from cylinders of this latter type a newly observed phenomenon is much more highly developed in the 150°C specimens. About 10 per cent of the grains show two sets of sharply defined lamellae intersecting at an anomalous angle of between 5° and 15°. In such a grain one set of lamellae (e_1 in Fig. 5) can be identified, by interfacial angles and by its relation to the *c* axis, as being parallel to one of the $\{01\bar{1}2\}$ planes of the crystal lattice. The other (e_1' in Fig. 5) necessarily is irrationally related to the same lattice. The pole e_1' invariably lies nearer the *c* axis than does the pole e_1; and in many grains e_1, e_1' and *c* are approximately cozonal. Two alternative interpretations are noted for future consideration as more data become available. Lamellae e_1' may possibly represent partings or twin lamellae inherited from the undeformed fabric and rotated through the crystal lattice to their present irrational position by translation gliding on other planes in the lattice (*e.g.*, one or both of the other $\{01\bar{1}2\}$ planes) during deformation. This possibility receives some support from the occasional occurrence of e_1' lamellae broad enough for a distinct optic orientation consistent with origin by twinning to be recognizable within the lamellae in question. But it is difficult to explain the generally rectilinear character of e_1' lamellae, or their lack of continuity across a given grain, in terms of such a mode of origin. Alternatively e_1' lamellae may perhaps have developed late in deformation by gliding on irrational surfaces inclined at low angles to an $\{01\bar{1}2\}$ plane, somewhat in the manner proposed by Fairbairn (1941) to account for lamellar structure in naturally deformed quartz. The latter possibility is supported by the observation that in rare cases e_1' offsets other lamellae, while in no case has e_1' been observed to be offset by other lamellae.

In several sections, just as in the case of marble deformed at room temperature, sparsely developed $\{02\bar{2}1\}$ lamellae (not recognizably twinned) appear in a minority of grains. The only other visible parting recorded is $\{10\bar{1}1\}$ cleavage.

Evidence of nonhomogeneous strain within a deformed cylinder was noted in some cases—

e.g., in a section cut parallel to plane 2 at one end of a T cylinder (321) compressed 20 per cent. In the central part of the section, the grains are more cloudy and have more densely spaced lamellae than those at the top and side of the section. The state of preferred orientation of c axis, as described later, confirms the obvious inference that strain has proceeded further in the central part of the cylinder than near the margin (especially the end margin). Measurement of average grain diameter in the direction normal to the foliation plane (3) in specimen 321 failed to show any consistent difference in grain size between more and less deformed sectors.

Petrofabric Analysis

Procedure.—Much the same procedure has been followed as for marble deformed at room temperature (Part III, p. 888–890). Measurements were made on 100 grains in a section cut parallel to T (*i.e.*, normal to the foliation) in all cases except T cylinders (306 and 321) deformed in compression. In these latter, sections cut parallel to plane 2 (also normal to the foliation) were used, and the measured poles were subsequently rotated into plane T. This modified procedure allowed more precise measurement of directions (especially c axes) which, as a result of deformation, had become aligned subparallel to the axis of applied stress —*i.e.*, at high angles to plane T. In every case it was possible to locate c axes, and all three $\{01\bar{1}2\}$ lamellae in more than 95 per cent of the grains on the measured traverse; so that corresponding orientation diagrams need not be corrected for the existence of a central "blind spot."

The c axis was located optically in all grains except certain highly twinned crystals in cylinders 252, 306, and 321, whose orientation favored $\{01\bar{1}2\}$ twinning. All visible $\{01\bar{1}2\}$ lamellae and $\{10\bar{1}1\}$ cleavages were measured in each grain and were identified by their mutual angular and zonal relationships. The same data were used to check the optically determined positions of the c axes, or to locate these where optical determination was impossible. There is a general tendency, noted also in marble deformed at room temperature, for the angle between c and the pole of $\{01\bar{1}2\}$ to exceed somewhat the theoretical value of 26½°. We offer no explanation for this effect, which must be connected with deformation since we have observed nothing comparable in undeformed Yule marble.

Orientation diagrams have been constructed for three crystal directions:

(1) The c crystal axis.

(2) Poles of most strongly developed $\{01\bar{1}2\}$ lamellae. One such is clearly recognizable in most grains. Where two sets are about equally strong in a given grain, both are plotted.

(3) Edges $[e{:}e]$ between the two strongest sets of lamellae in each grain. In the majority of grains one set (e_1) is well developed, a second set (e_2) somewhat less so, and the third set (e_3) is inconspicuous or lacking. Axes a_1, a_2, a_3 were plotted in two cases (176, 321) but yielded no consistently recognizable pattern. Spacing indices for individual sets of $\{01\bar{1}2\}$ lamellae were not determined in this series of fabric analyses.

Preferred orientation of optic axis c.—In the undeformed marble fabric the c axes of calcite grains tend to lie at high angles to the plane of foliation (faces 1 and 3). In corresponding orientation diagrams (Fig. 6) there is a distinct but somewhat dispersed maximum around the pole of faces 1 and 3. This pattern may still be recognized as an element in the fabrics of deformed marbles even where the strain is of the order of 20 per cent. It is most persistent in the fabric of cylinders whose orientation in relation to applied stress precludes twin gliding in the majority of grains (Fig. 7, B, C). Such behavior accords completely with predictions based on the hypothesis of homogeneous deformation put forward by Handin and Griggs (Part II).

Compression at right angles to the foliation (255; Fig. 7, B) and extension parallel to it (176; Fig. 7, C) sharpen the original concentration of c axes. In both cases, c axes have been eliminated (presumably by nearly complete twinning) from the central part of the diagram.[1]

[1] From a statistical standpoint this is only a minor feature of the fabric, subject to over or underemphasis in a fabric analysis based on as few as 100 measurements. We have therefore verified the nonexistence of c axes in the central areas of Figures 7,B and 7,C by rapid traverses of several hundred grains in sections cut parallel to T (the plane of projection).

In Figure 7, B the maximum which coincides with the direction of shortening is strong and sharply defined compared with the narrowed but more extended maximum of Figure 7, C. The latter has been drawn out into an incomplete girdle in the plane normal to the axis of extension of the specimen. Note, too, how the few *c* axes initially subparallel to the foliation but normal to the axis of extension survive unchanged at the north and south poles of Figure 7, C, thus emphasizing further the partial girdle pattern of this diagram. No such *c* axes survive in Figure 7, B, for in this case corresponding grains were favorably oriented for twinning on $\{01\bar{1}2\}$.

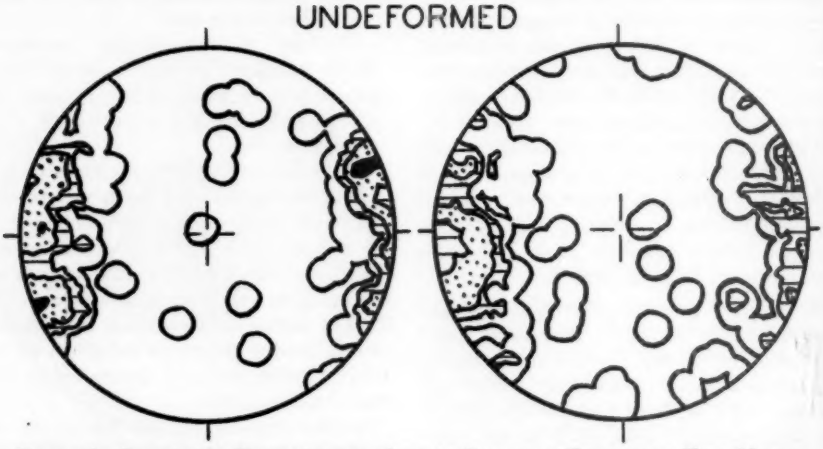

FIGURE 6.—ORIENTATION DIAGRAMS FOR *c* AXES OF CALCITE IN UNDEFORMED YULE MARBLE
100 grains per diagram. Contours, 1, 3, 5, 10%, per 1% area. The pole of the *B* surface of the block is at the center (lower hemisphere). Foliation is normal to plane of diagrams, parallel to N-S diameters.

Figures 7, A (321; compression parallel to foliation) and 7, D (252; elongation normal to foliation) are orientation diagrams constructed for specimens in which the majority of grains are strongly twinned on one or more $\{01\bar{1}2\}$ planes. In many such grains there is a choice between two alternative positions of *c* axes, one in the original lattice, the other in the lattice newly developed by twinning on $\{01\bar{1}2\}$. The *c* axis of that lattice which occupies the greater aggregate area within a given grain has been plotted in each case. There are a few grains where the initial and the twinned lattice are about equally developed; and here both *c* axes have been plotted. In both diagrams the initial pattern, though not destroyed, is in process of being obliterated. In Figure 7, A a new central concentration of *c* axes is developing. Note that this is parallel to the axis of compression, indicating not only that corresponding grains have been twinned to a high degree but that they have been rotated through angles of the order of 10° to 30°, so that their *c* axes approach the axis of compression. The pattern of Figure 7, D is distinctly weaker, since stress conditions in this case have dispersed *c* axes of twinned lattices through a broad vertical zone wherein they lie at high angles to the axis of extension.

Figure 7, E shows the orientation pattern resulting from extension in a direction inclined at 45° to the foliation. The initial concentration of *c* axes, though still recognizable, has been skewed away from the axis of extension, perpendicular to which a girdle of *c* axes is in process of formation. Twinning on $\{01\bar{1}2\}$ is the only glide mechanism powerful enough to eliminate the majority of *c* axes from the top right and lower left quadrants of the diagram. Its effectiveness is confirmed by plotting separately the two possible positions of *c* axes for each of a number of grains (18 per cent of those measured) in which twinning is so obvious that there are two alternative *c* directions. Such are interpreted as crystals whose

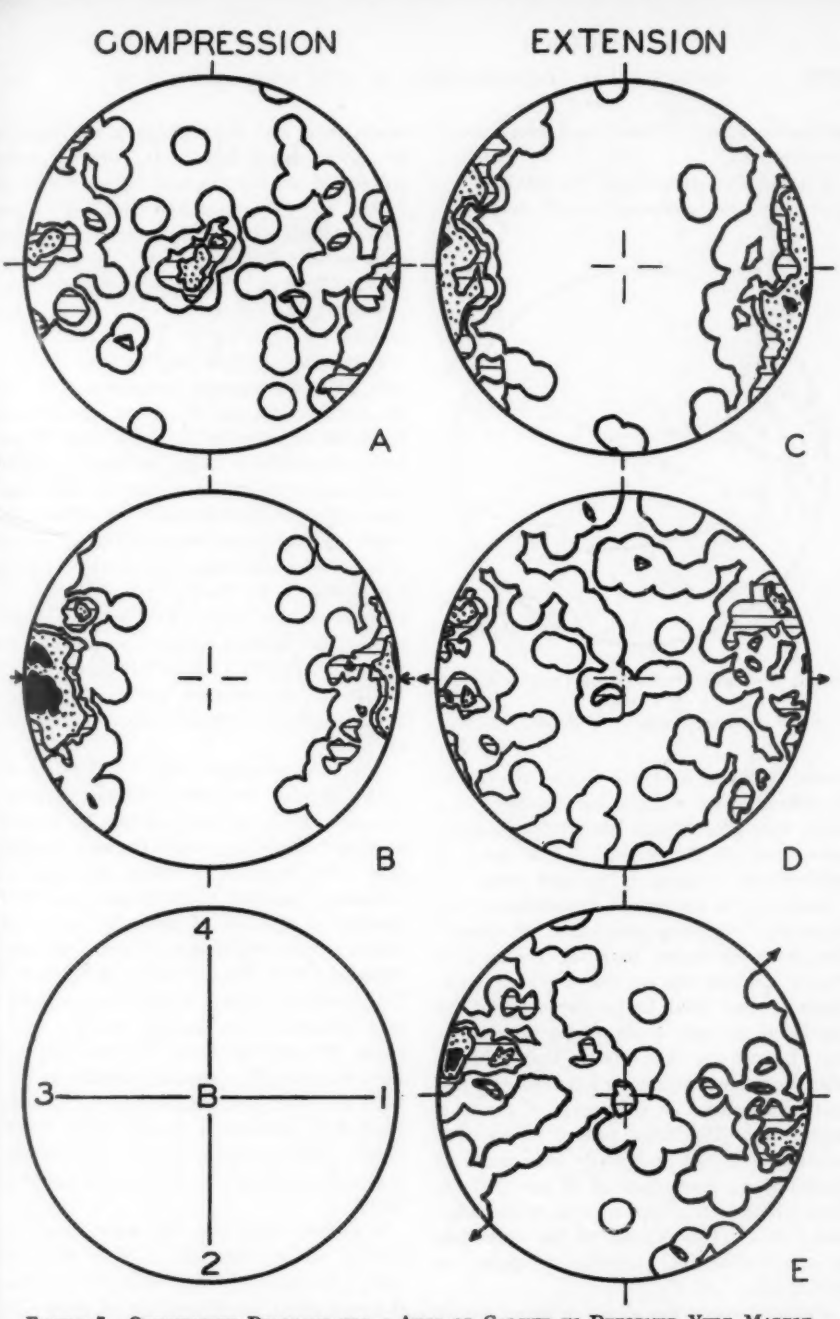

FIGURE 7.—ORIENTATION DIAGRAMS FOR *c* AXES OF CALCITE IN DEFORMED YULE MARBLE
100 grains per diagram. Contours, 1, 3, 5, 10%, per 1% area. Diagrams oriented (*cf.* bottom left) with trace of foliation plane (1 and 3) parallel to N-S diameters.

A. 321, *T* cylinder, shortened (normal to plane of diagram) by 20%.
B. 255, *3* cylinder, shortened (E-W) by 19%.
C. 176, *T* cylinder, elongated (normal to plane of diagram) by 12%.
D. 252, *3* cylinder, elongated (E-W) by 20%; 111 *c* axes in 100 grains.
E. 287, *d* cylinder, elongated (NE-SW) by 20%.

lattices have been twinned more than halfway to completion.

Poles of alternative *c* axes for grains of this type are shown, connected in each case by an

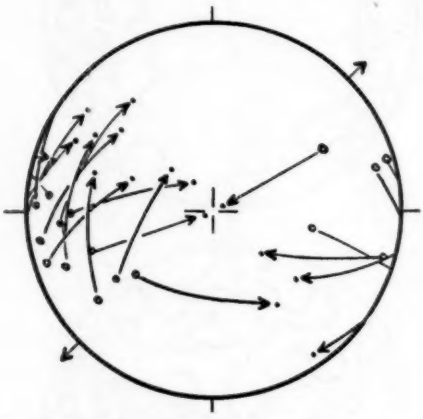

FIGURE 8.—PAIRS OF *c* AXES FOR TWINNED GRAINS OF CALCITE
287, *d* cylinder, elongated (NE-SW) by 20%.

arrow, in Figure 8. The *c* axis of the better-developed lattice in each case is plotted as a black dot; that of the less-extensive lattice, interpreted as the original lattice prior to deformation, is shown by an open circle.

Some general conclusions, independent of any hypothesis regarding mechanism of orientation, may be drawn from the diagrams of Figure 7: Under the conditions of our experiments, *c* axes tend to become concentrated parallel to the axis of shortening in compression experiments. Conversely, they tend to align themselves within a girdle normal to the axis of elongation in the course of extension experiments. The initial pattern of preferred orientation is not completely obliterated in experiments where strain of 20 per cent has been achieved. It is least affected where orientation of the test cylinder in the stress field is unfavorable for twinning of grains on $\{01\bar{1}2\}$ (Fig. 7, B, C).

Preferred orientation of best-developed $\{01\bar{1}2\}$ lamellae.—Orientation diagrams for strongly developed $\{01\bar{1}2\}$ lamellae—one set per grain in most cases—show consistently reproducible patterns illustrated in Figure 9. These are symmetrical with respect both to the direction of applied stress and to the original *c*-axis pattern of the undeformed fabric; for in all grains, even those strongly twinned on the $\{01\bar{1}2\}$ lamellae in question, the most conspicuous set of lamellae is parallel to one of the $\{01\bar{1}2\}$ planes of a crystal lattice that has been rotated at most through 20°–30° from its initial position.

In lamellae patterns resulting from compression, poles are strongly concentrated as near as possible to the axis of applied stress, within the limits imposed by the *initial* state of preferred orientation of *c* axes. In Figure 9, B (255, compression normal to foliation) this maximum coincides approximately with that of the *c*-axis diagram of the initial fabric, and so too with its intensified equivalent in the deformed fabric (Fig. 7, B). In Figure 9, A (321, compression parallel to foliation) poles of prominent $\{01\bar{1}2\}$ lamellae occupy a ring around the axis of compression; and within this are areas of strong concentration about halfway between the axis of compression and the *c*-axis maximum.

The three diagrams (Fig. 9, C, D, E) for $\{01\bar{1}2\}$ lamellae in fabrics deformed by extension are alike in that poles of lamellae are concentrated in girdles around the axis of extension. This expresses a strong tendency for prominent lamellae to be aligned as nearly parallel to the axis of extension as is permitted by the *initial* state of preferred orientation of *c* axes. The cleft girdle of Figure 9, D (252, extension normal to foliation) occupies a zone situated at an angular distance of between 30° and 60° from the extension axis. Figures 9, C (176, extension parallel to foliation) and 9, E (287, extension at 45° to foliation) show great-circle girdles whose incompletely filled condition reflects the influence of preferred orientation of *c* axes in the *initial* fabric.

Preferred orientation of edges [e:e].—As pointed out in Part III (p. 901), the *c*-axis orientation pattern of the initial fabric imposes this restriction on the pattern of edges [*e*:*e*]: such edges, lying at 76 degrees to the *c* axis of the grain in question, must be concentrated within a broad belt along the N-S diameter of the orientation diagram (trace of foliation).

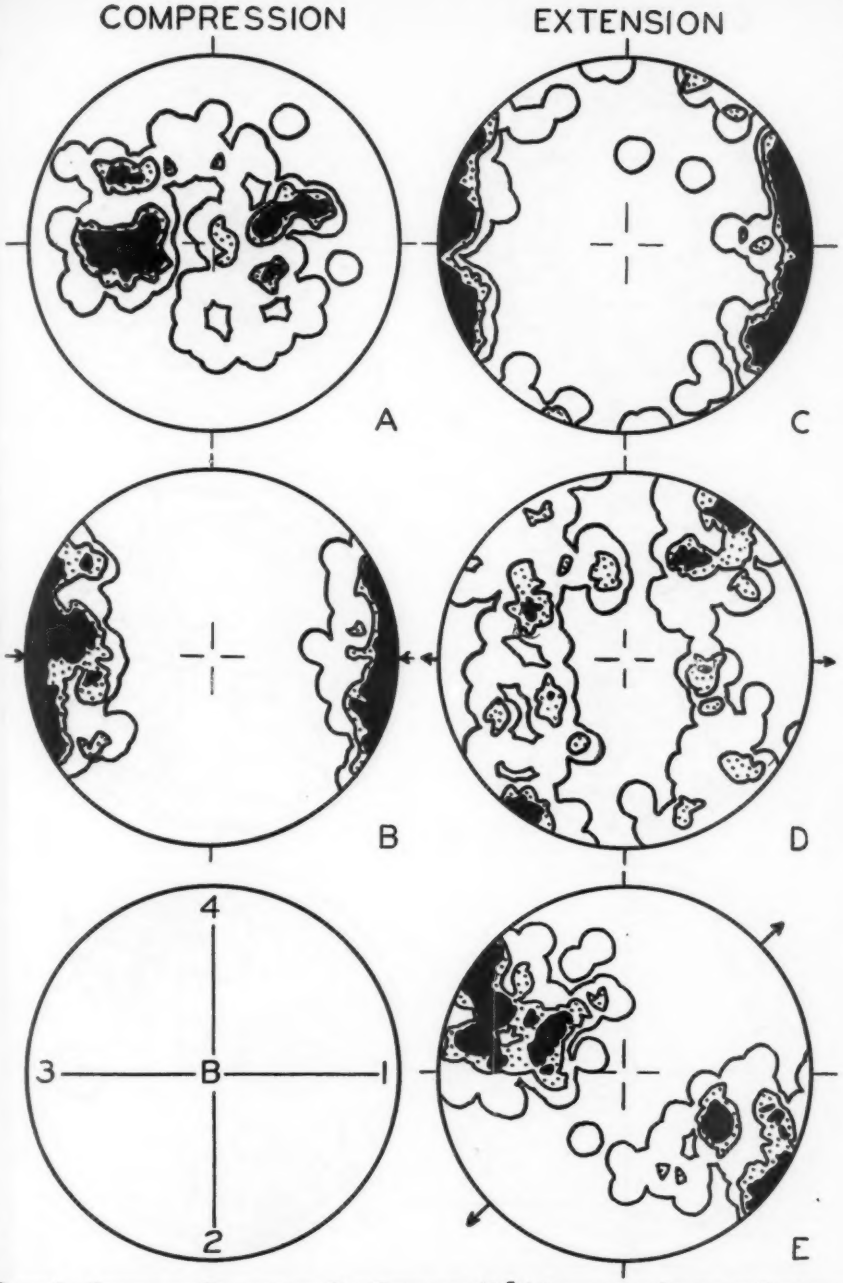

FIGURE 9.—ORIENTATION DIAGRAMS FOR BEST-DEVELOPED {01$\bar{1}$2} LAMELLAE IN CALCITE OF DEFORMED YULE MARBLE

100 grains per diagram. Contours, 1, 3, 4%, per 1% area. Orientation of diagrams is given at bottom left (lower hemisphere).

A. 321, *T* cylinder, shortened (normal to plane of diagram) by 20%; 101 lamellae.
B. 255, *3* cylinder, shortened (E-W) by 19%; 122 lamellae.
C. 176, *T* cylinder, elongated (normal to plane of diagram) by 12%; 125 lamellae.
D. 252, *3* cylinder, elongated (E-W) by 20%; 123 lamellae.
E. 287, *d* cylinder, elongated (NE-SW) by 20%; 112 lamellae.

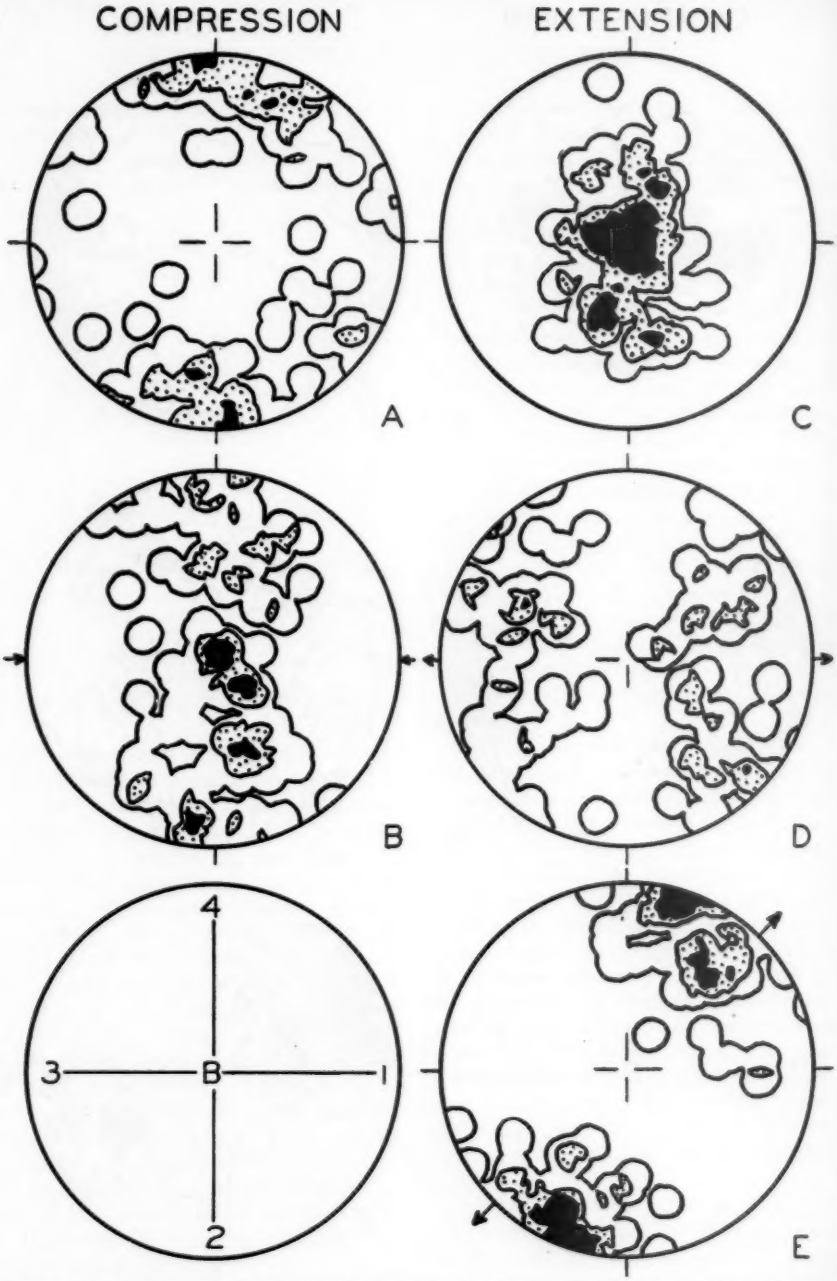

FIGURE 10.—ORIENTATION DIAGRAMS FOR EDGES [*e*:*e*] IN CALCITE OF DEFORMED YULE MARBLE

100 grains per diagram. Contours, 1, 3, 6%, per 1% area. Orientation of diagrams is given at bottom left (lower hemisphere).

A. 321, *T* cylinder, shotened (normal to plane of diagram) by 20%; 93 edges.
B. 255, *3* cylinder, shortened (E-X) by 19%; 105 edges.
C. 176, *T* cylinder, elongated (normal to plane of diagram) by 12%; 100 edges.
D. 252, *3* cylinder, elongated (E-W) by 20%; 85 edges.
E. 287, *d* cylinder, elongased (NE-SW) by 20%; 82 edges.

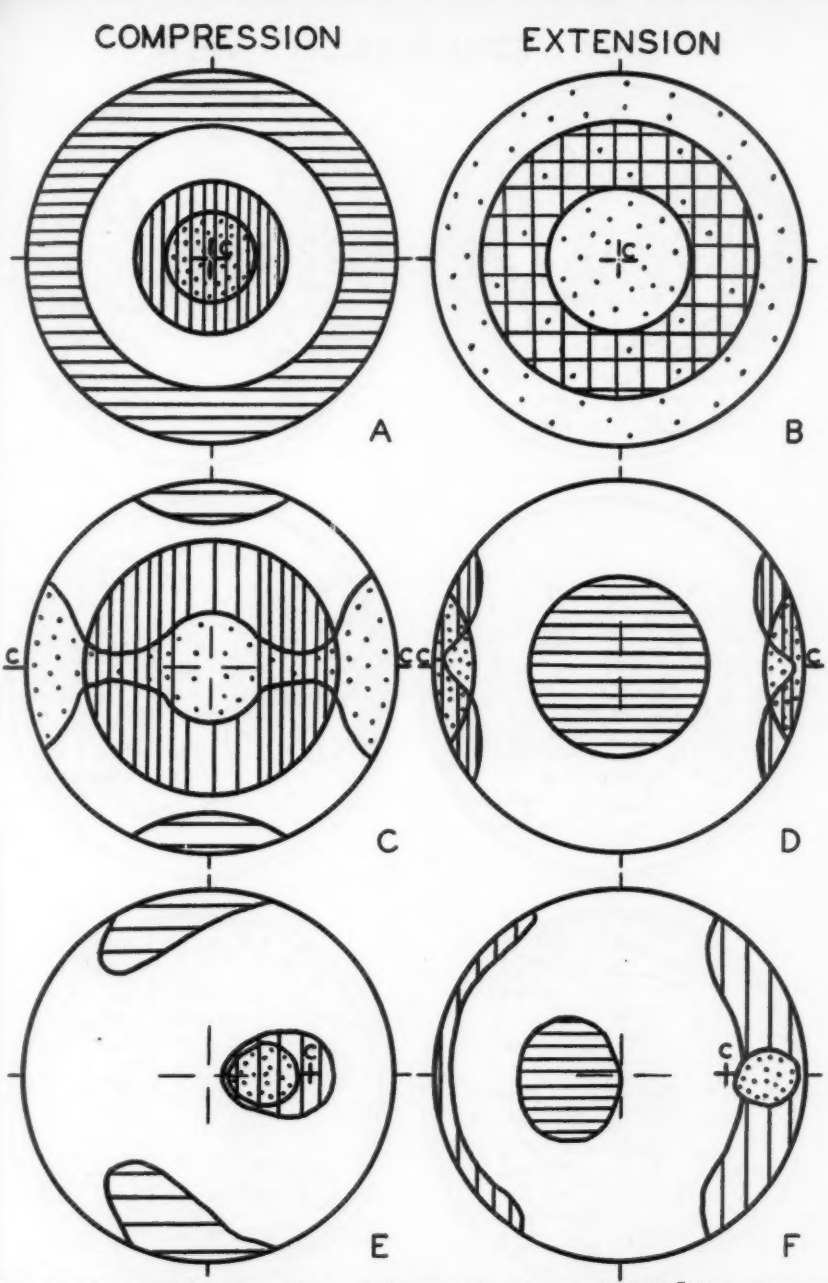

FIGURE 11.—IDEALIZED ORIENTATION DIAGRAMS SHOWING MAXIMA FOR *c* AXES, {01$\bar{1}$2} LAMELLAE, AND [*e*:*e*] EDGES, IN RELATION TO APPLIED STRESS AND PRE-DEFORMATIONAL FABRIC

Axis of applied stress (Compression in A, C, E; Extension in B, D. F) is normal to plane of diagrams. The *c* axes of the initial fabric were concentrated around points *c*. Maxima for *c* axes in deformed fabric are stippled; maxima for poles of conspicuous 01$\bar{1}$2 lamellae are ruled vertically; maxima for edges [*e*:*e*] are ruled horizontally. Density of stippling or ruling indicates relative concentration within maxima.

A, B, Applied stress axis parallel to dominant *c* axes of initial fabric.

C, D. Applied stress axis normal to dominant *c* axes of initial fabric.

E, F, Applied stress axis inclined at 45 to dominant *c* axes of initial fabric.

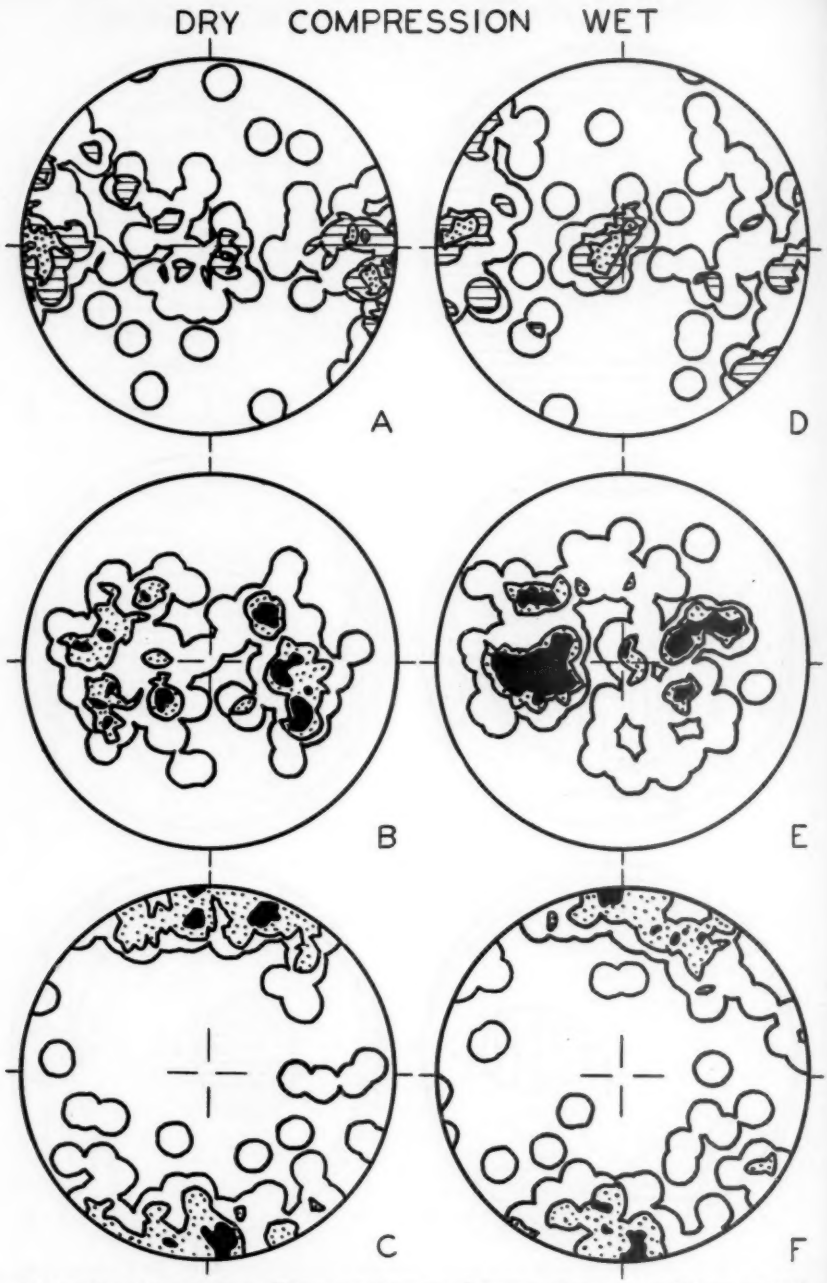

FIGURE 12.—COMPARISON OF FABRICS OF MARBLES DEFORMED DRY AND IN WATER AT 150°

Compression of *T* cylinders, shortened (normal to plane of diagrams) by 18% (A, B, C) and 20% (C D, E) respectively. 306 (A, B, C), dry at 150°C. 321 (D, E, F), in water at 150°C.

A, D. *c* axes in 100 grains; contours, 1, 3, 5%, per 1% area.

B, E. Best-developed {0112} lamellae in 100 grains; contours, 1, 3, 4%, per 1% area.

D, F. Edges [*e*:*e*] in 100 grains; contours, 1, 3, 6%, per 1% area.

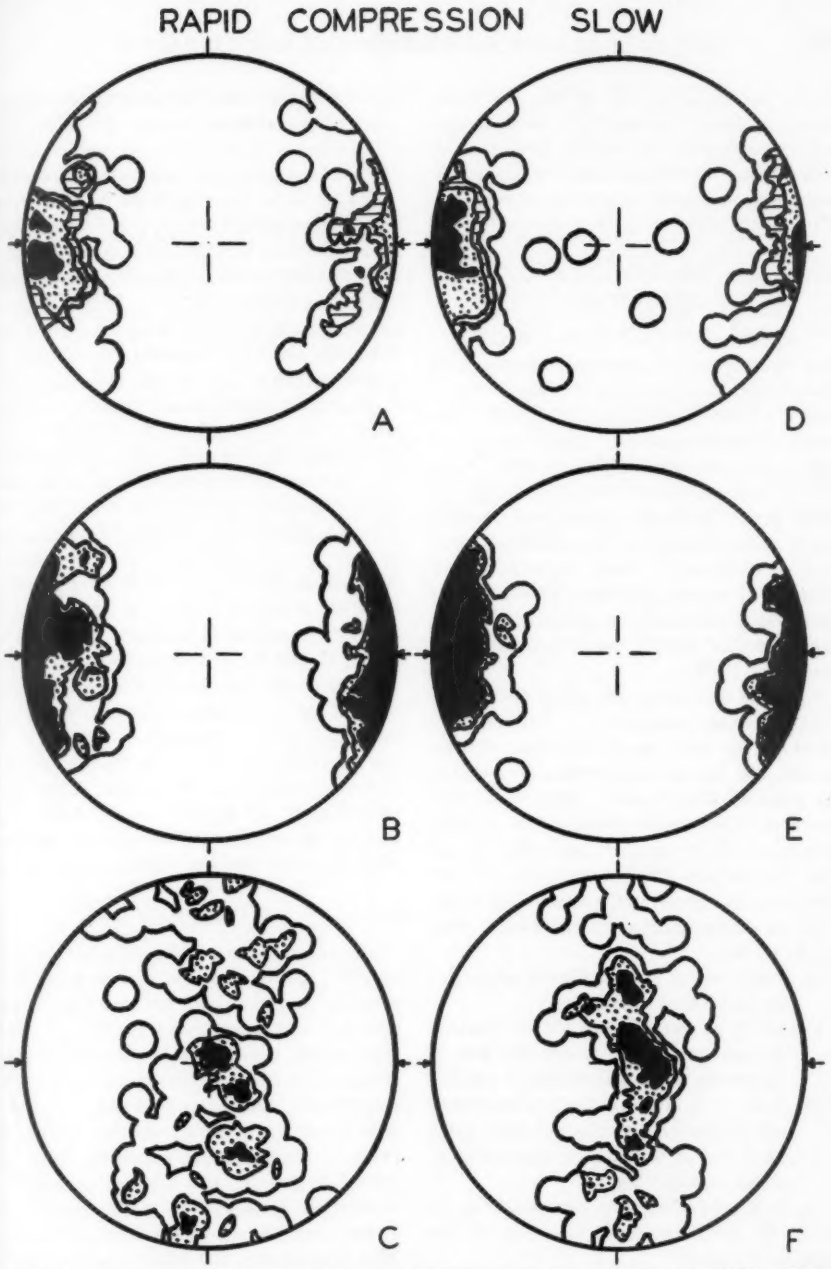

FIGURE 13.—COMPARISON OF FABRICS OF MARBLES DEFORMED RAPIDLY AND SLOWLY AT 150°C IN WATER

Compression of 3 cylinders, shortened (E-W) by 19%. 255 (A, B, C), duration of experiment 14 minutes. 260 (C, D, E), duration of experiment, 7 hours.

A, D. *c* axes in 100 grains; contours, 1, 3, 5, 10%, per 1% area.

B, E. Best-developed {01$\bar{1}$2} lamellae in 100 grains; contours, 1, 3, 4%, per 1% area; maximum concentration in each, 10%.

D, F. Edges [*e*:*e*] in 100 grains; contours, 1, 3, 6%, per 1% area.

Within the limits imposed by this restriction, the diagrams of Figure 10 are alike in that maxima consistently develop as far as possible from the axis of compression (Fig. 10, A, B), or as close as possible to the axis of extension (Fig. 10, C, D, E).

Influence of Temperature, Water, Time on Deformed Fabric

Temperature.—We now have a quantity of data relating to deformation, respectively at room temperature (*cf.* Part III) and at 150°C under otherwise identical conditions. The trends of fabric evolution appear to be the same in the two cases. Some of these trends were rather imperfectly established in our earlier work (Part III), since optical measurements were hindered by the inhomogeneously strained condition of many grains in marble deformed at room temperature. However, these same trends are clearly recognizable and have been confirmed beyond doubt in material deformed at 150°C.

Figure 11 summarizes the effects of deformation, involving elongation or shortening by about 20 per cent, upon the fabric of Yule marble. The axis of applied stress is normal to the plane of the diagrams which show ideal locations of respective maxima for *c* axes, prominent $\{01\bar{1}2\}$ lamellae, and edges of the type [*e*:*e*] for six different orientations of applied stress in relation to the same initial fabric.

(1) In fabrics affected by *compression* (Fig. 11, A, C, E):

(a) *c* axes tend to become aligned subparallel to the axis of shortening;

(b) the most conspicuous $\{01\bar{1}2\}$ lamellae in each grain tend to cut the axis of shortening at as high angles as possible

(c) edges [*e*:*e*] between the best-developed sets of $\{01\bar{1}2\}$ lamellae of each grain tend to cut the axis of shortening at angles approaching 90°.

(2) In fabrics affected by *extension* (Fig. 11, B, D, F) the fabric tends to change in the opposite direction:

(a) *c* axes tend to concentrate at high angles to the axis of elongation;

(b) the most conspicuous $\{01\bar{1}2\}$ lamellae develop as nearly parallel to the axis of elongation as is permitted by orientation of the crystal lattices;

(c) edges [*e*:*e*] tend to be as nearly parallel to the axis of elongation as is possible.

We conclude that the main mechanism of deformation, as reflected in the deformed fabrics, is the same at 150°C as at room temperature. The chief difference is the more obviously distorted condition of many grains in low-temperature fabrics, and the generally sharper definition of preferred-orientation patterns in high-temperature fabrics of Yule marble.

Water.—In several cases deformation experiments were duplicated at 150°C, respectively, in the presence and in the absence of water. Corresponding fabrics resulting from one such pair of experiments are illustrated in Figure 12. The two fabrics are virtually identical; and it may be concluded that for marble rapidly deformed at 150°C water has little or no effect upon the resultant fabric.

Time.—Two sets of diagrams in Figure 13 (A, B, C, and D, E, F respectively) illustrate the nearly identical nature of fabrics resulting respectively from rapid and from slower deformation, both in presence of water. In the one case (255, Fig. 13, A, B, C) the duration of the experiment was 14 minutes; in the other (260, Fig. 13, C, D, E) it was 7 hours. The more slowly deformed fabric seems to be somewhat the more sharply defined of the two.

Conclusion

The lower strength of Yule marble observed at 150°C as compared to that at room temperature, and the more uniform texture suggest that a significant step has been made in approaching the effects of natural environmental conditions. Contrary to expectation, temperature, time, and presence of water—factors subject to wide variation within the limits of geological environments—have had little influence on the patterns of preferred orientation developed in calcite marble deformed under the conditions of our experiments. This suggests that the fabrics recorded in this paper and in Part III may have greater geological significance and may prove of greater use in interpreting fabrics of some natural marbles than was at first anticipated.

Experiments at 300°C and fabric studies of the deformed material are now under way.

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Short Notes

SUBMARINE TOPOGRAPHY IN THE NORTH ATLANTIC

By Bruce C. Heezen, Maurice Ewing, and D. B. Ericson

The writers wish to offer some new interpretations of the topographic features described by their coworker Ivan Tolstoy in his paper *Submarine topography in the North Atlantic* (1951). The key to these new interpretations came as a result of a co-ordinated topographic and sedimentary survey of the seaward extension of the Hudson Canyon undertaken during the summer of 1949. At the time Tolstoy wrote his paper (September 1949) the sedimentary data had not been sufficiently studied to reveal the principle upon which these new interpretations are based. When only the topographic evidence was considered the existence of the striking streamlike characteristics of the bottom of the ocean basin at 2600 fms, 300 nautical mi. from shore seemed to demand a tremendous eustatic shift of sea level. The sediments, however, demanded a submarine origin for the canyons. It was found that the canyon floors are covered by gravel and sands; on the canyon walls crop out Tertiary sediments in the deeper portions of the extension as well as in the previously (Northrop and Heezen, 1951; Stetson, 1936; 1944) explored portions on the continental slope. On the inter-canyon portions of the continental rise (that portion of the ocean floor which gently slopes basinward from the base of the continental slope) "normal" Recent fine sediment (blue mud) was found. These findings give clear evidence that erosion and transportation is or has recently been active in the canyons but not, or at least not to such a great degree, on the intervening areas of the continental rise. The great distances, the low gradients indicate that the agent with the requisite mobility was most probably turbidity currents. When it was so well established that the submarine canyons were at the very least avenues through which great quantities of sand, gravel, and mud traveled, the question of where the material was deposited demanded attention. At the ends of the canyons extensive deposits of sand were discovered (Ericson, Ewing, and Heezen, 1951). If the canyons were cut by turbidity currents a tremendous volume of sediment must have passed through them, and a great but considerably smaller volume of sediment must have been eroded along the channels to form the canyons observed today. Even if the canyons were not cut by turbidity currents but have subsequently been avenues for such currents, there must have been a vast quantity of sediment carried along the canyons and deposited in the ocean basin. The area of sand deposition is immediately adjacent to the base of the continental rise near the ends of the channels of the submarine canyons. The lutite fraction of the load must be deposited farther out in the basin. The normal sediment which settles through the water in these depths (over 2600 fathoms) is red clay, but it has long been known that locally cores of gray clay taken in these depths will have abnormally high concentrations of calcium carbonate in respect to their depth. These gray clays may be washed in along the bottom from shallower areas by turbidity-current flow. Although various workers have championed submarine slumps, submarine landslides, and turbidity currents, the great mobility and vast importance of turbidity currents in submarine sedimentation and submarine geomorphology has not generally been recognized, even by their strong proponents. Kuenen (1950), who was largely responsible for bringing turbidity currents to the attention of the geological profession, shows in his book that he did not suspect their vast significance in oceanic sedimentation, for nowhere in his discussions of the bathyal or abyssal environments did he mention turbidity currents as a significant or even minor contributor to the sedimentary history of the province. Wiseman and Ovey (1950) believe that sedimentation can be affected by

slumps at the bases of steep slopes, but they say nothing of transportation along the bottom into the flat basins.

Tolstoy describes several vast smooth or gently sloping plains which cover the floors of the ocean basins. If we consider turbidity currents as an important force on the ocean floors, as is indicated by the evidence from the canyons, these flat floors can be explained as the result of the filling of the basins by turbidity currents and other transportation along the bottom. Sea mounts rising from these plains do so abruptly (Tolstoy, 1951, p. 444). There is no transition zone, no gradual approach; the slope of the sea mount and the flat ocean floor join to form a sharp angle. The buried appearance may well be due to the fact that the bases of these sea mounts are being buried as sediment fills up the basins. Tolstoy indicates that in various places, where the different flat plains of the ocean floor join, they do so in a steplike fashion. He also states that in other places one grades into another. Both of these situations can be explained through the action of turbidity currents. The abrupt steplike transitions may occur where the original basins were separated by a sill at approximately the depth of the shallower of the two present plains; when the shallower one filled up to this sill a sharp steplike transition from one plain to the other existed, but as the sediment poured from the shallower basin into the deeper basin a gradational transition eventually developed. Tolstoy states that the 2850–2950 fathom plain gradually deepens to the south, and near Latitude 30° it is broken by a series of northeast-southwest trending tonguelike flat-bottomed valleys. Their flat bottoms indicate they have been filled with sediment. These tongues begin at 2900 fathoms, the depth of the flat plain at that latitude, and approach 3200 fathoms, the depth of the flat floor of the Nares Deep to the south. They may be canyons cut into the 2850–2950 fathom plain due to some rejuvenation of the turbidity flow in this region, or more likely they represent the partially buried topography of a tectonic feature which acted as a sill between the northern and southern plains.

Tolstoy divides the Mid-Atlantic Ridge into three roughly parallel zones: (1) the high central zone with rocky precipitous mountains; (2) the intermediate zone flanking the central zone on each side, consisting of hills and intervening level plains or "terraces" at various levels from 1600 to 2500 fathoms; (3) the outer mountainous zone, a region of rugged relief separating the 2850–2950 plain and the terraced or intermediate zone. Tolstoy quotes Press and Ewing, stating that the "terraces" of the intermediate zone are underlain by relatively great thicknesses of sediment as indicated by the reflection seismograph. The rocky slopes of the main range indicate that the present and geologically recent sediments have been swept from that zone. It is here suggested that much of the sediment which was swept from the main range was deposited in the intermediate zone and that the terraces are miniature deep sea plains and most of the original topography is buried. Tolstoy states that in the area immediately south of the Azores the "whole length of the boundary between the foothills and the terraced zone is characterized by an essentially continuous ridge shoaling in many places to appreciably less than 2000 fathoms", but that north of the Azores it is difficult to trace the terraced or foothill zones. The outer mountainous or foothill zone, where well expressed, may act as a sill preventing turbidity-current channels from cutting into the intermediate or terraced zone and thus making it possible for these small basins to become filled well above the level of the deep plains by sediment eroded from the main range as well as sediment settling through the water. North of the Azores where the outer zone is not well expressed the sediment is carried out to the deep plains and no terraced zone is developed. The terraced zone may differ in no significant tectonic way from the outer mountainous zone, but merely be buried so that only the higher hills are visible. The source of the sediments filling up these basins is in the case of the terraced zone the adjacent Mid-Atlantic Ridge, in the case of the deep plains both the continents and their adjoining shelves and the Mid-Atlantic Ridge and other oceanic elevations. Much of the material in the North America Basin may be glacial in origin, but much of it may have been carried along the bottom by turbidity

currents rather than along the sea surface by icebergs. Unpublished data on the topography of the Puerto Rico Trough obtained by Hersey in 1949 and additional information by Ewing and Heezen obtained in 1951 show that it too has a flat bottom, indicating that it is being filled by sediment much of which must be carried in by turbidity currents. Much of stratigraphy must be reviewed with these new concepts in mind. Complete reports on the topography and sediments of the Hudson and other canyons, the deep plains, the Puerto Rico Trough, the terraced zone, and other related subjects are being prepared at the Lamont Geological Observatory.

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MECHANISM OF WEATHERING—A REPLY

BY A. F. FREDERICKSON

Recently McConnell (1951) has commented on a paper of mine entitled *Mechanism of weathering*, in which he recommends consideration of the hypothesis because it ". . .may contain elements of realism. . . .", but criticizes it because:

(1) it allegedly does violence to existing terminology, and

(2) ". . . .certain portions of the discussion contain incompatibilities which were not adequately treated."

He feels, however, that . . . "Further consideration of the subject therefore seems desirable." It is indeed reassuring to find that another (McConnell) feels the hypothesis deserves consideration.

McConnell complains about my use of the term "base exchange", and then devotes space to criticizing a quotation attributed to Wiegner including a notation "$HAlSi_3O_8$". He comments that ". . . this expression lacks realism because the existence of $HAlSi_3O_8$ has never been demonstrated." The writer agrees that the existence of solid $HAlSi_3O_8$ has never been demonstrated, but since neither that expression nor Wiegner was referred to in the article criticized, these comments of McConnell's hardly constitute a valid criticism of the paper or pertain to my use of the term "base exchange". I heartily agree with McConnell's last sentence which states: "Admittedly Wiegner and a few others have contributed greatly to the confusion which now exists."

McConnell repeats the argument used in my original paper—that hydrogen ions (protons) migrate into the structure of albite and repulse the Na ions which leave the albite. He wishes to entertain an alternative proposition: "That the Na ions escape first and are instantaneously replaced by H ions from the water." What is the practical difference between a hydrogen ion taking the place of a sodium ion, or a sodium ion being *instantaneously* replaced by a hydrogen ion?

Apparently McConnell agrees with the writer but merely wishes to change the order of words in the presentation.

McConnell objects to the writer's use of the term "base exchange", and cites the meaning of base exchange in terms of repeatedly reversible, water-softening treatment by the use of zeolites. Way (1850) observed the phenomenon of ion exchange long before permutites were used as water softeners, and the use of the term "base exchange" has long been history. Base exchange is a widely used term of rather *general* meaning, and it was so used by the writer.

McConnell is apparently unaware that the term base exchange does *not* imply equal ease of exchange between cations (a measure of the tenacity by which they are held by the crystal lattice) even between the Na^+ and Ca^{++} ions cited by him. The zeolites, because of their rarity, are of almost negligible importance in weathering and soil-forming processes.

The behavior of potassium in soils and on clays is one of the most important chemical "reactions" affecting mankind because of its influence on the health and growth of certain agricultural products. The fixation of potash during potash fertilization is one of the most widely studied exchange reactions. The literature on this subject is very voluminous; summaries can be found in Kelley (1948), Marshall (1949), and Gieseking (1949). In general, potassium, once exchanged onto a clay mineral, is often very difficult to get off again. Under certain circumstances, it is "fixed" onto the clay. This can hardly be considered as a completely reversible process. In a like manner, ions such as zinc not only occupy the "exchange positions" but also enter the crystal lattice of clays, and certain other minerals, in positions from which they cannot be removed without destroying the crystal lattice of the mineral. Elgabaly (1950) has recently discussed this subject in detail and has offered excellent

experimental evidence to support the view that base exchange is *not* a completely reversible process under all circumstances as is believed by McConnell.

Where ions are solely involved, and they are clear-cut cases of simple cations or *anions* (rather than amphoteric substances like the aluminum hydroxides, charged colloidal micelles, chelate groups, complexes, silica gels etc.), the terms cation exchange, anionic or ionic (more general) exchange would be more definitive and preferable to "base exchange". All of us recognize our limitations of knowledge about the *exact* behavior of Al and Si ions as they are released during weathering. Would not severe violence have been done to terminology and scientific integrity if a specific term were applied to a mechanism still lacking complete understanding?

McConnell (p. 701).

"... wonders why the entire discussion of the breakdown of the feldspar crystal has been restricted to consideration of the Na ion. Dissolution of Al and Si takes place simultaneously although at slower rates."

Did McConnell fail to read the section of my paper (p. 230) entitled "Final Stages in the Weathering Process" wherein the breakdown of the feldspar structure was discussed following Murata (1946)? After quoting the first line of the summary, did he fail to see the last line of the same paragraph which stated that "... The minerals will break down into colloids or small clumps of insoluble silica. ..."?

As one reads McConnell's "... Further consideration of the subject" (from his first paragraph) it appears that he is adjusting his thinking to the mechanism of weathering as was originally presented. He apparently would prefer, however, to change the word order or present the same idea in a different style.

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SUBMARINE EROSION, A DISCUSSION OF RECENT PAPERS

BY FRANCIS P. SHEPARD

INTRODUCTION

Papers in the Bulletin by Woodford (1951), Ericson, Ewing, and Heezen (1951), and an abstract by Crowell (1950) all point to a submarine origin for submarine canyons. The papers are very thought-provoking and should cause advocates of subaerial origin of submarine canyons to give serious reconsideration to their opinions. The importance of submarine processes is indicated by the enormous quantities of sand that have been carried, persumably by turbidity currents, out of the Hudson Canyon and distributed out over the deep sea plain beyond (Ericson *et al.*, 1951). The evidence that these sand movements have continued up to recent times is equally significant. This information might have been even more impressive had it been more documented and if it had been supported by reference to the recent work of the Swedish Deep-Sea Expedition and of the Scripps Institution and Navy Electronics Laboratory which has shown the presence of sand of similar characteristics out over many other parts of the ocean floor (Arrhenius, 1950; Shepard, 1951a; and papers by F. B Phleger, J. C. Ludwick, H. W. Menard, and F. P. Shepard in a symposium presented before the Society of Economic Paleontologists and Mineralogists meeting in Chicago, April 1950).[1] The present writer has referred to the movement of sediment out along submarine canyons in numerous papers for the past 20 years although it is only recently that the evidence has shown how far seaward this material is carried and what huge quantities are involved.

Woodford's valuable paper does not contribute new information from the sea floor, but it does show the failure of a simple submergence hypothesis to account for the gradients of typical sumbarine canyons and presents evidence, as does Crowell's paper, that the upper parts of the submarine canyons have walls consisting of Pleistocene and probably post-Pleistocene material. This last point might indicate that the cutting is still in process and thus infers that the canyons are of submarine origin. (For another interpretation, *see* Shepard, 1951b.)

These papers appear to be convincing, but they all fail to discuss most of the serious objections to submarine erosion as the underlying cause of the canyons and they overlook the numerous characteristics of submarine canyons which favor an initial erosion by rivers. Insofar as the writer knows, no information has yet been produced which rules out the hypothesis that the canyons were originally cut by streams in the remote past and have since been maintained and modified by landslides and other marine processes (first suggested by Shepard, 1934; most recent revision, Shepard, 1951b). If such evidence exists, its presentation would be much appreciated by all. Advances are being made so fast in submarine geology that hypotheses should be kept in a fluid state.

CANYON CHARACTERISTICS AND SUBMARINE ORIGIN

Delta-front Depressions

In considering the type of submarine feature which might be expected to exist if the valleys of the sea floor are primarily the product of subaqueous erosion, attention should be called to the valleys which are known to exist on the fronts of deltas, particularly where those deltas have been built out onto steeply sloping sea or lake floors. These are the only sure cases of subaqueous valley formation. The valleys of the Swiss deltas are well known (*see* Woodford, 1951, Fig. 8A; Kuenen, 1950, Fig. 227), and similar features occur on the fronts of some deltas built into the ocean. These valleys are rather typical of landslide scars having broad-

[1] Appearing in Jour. Sedim. Petrol., Bull. for October or November 1951.

floored, shallow, and irregular troughs with leveelike elevations along the sides of their outer courses. In some places they have distributaries. Similar features are found along the lower shallow valley extensions of submarine canyons, but the main portions of the canyons are typical river canyons and entirely different from the delta-front depressions. The submarine-canyon characteristics will be considered individually.

Submarine-Canyon Tributaries

It is notable that delta-front valleys have few if any tributaries. Woodford states (p. 842) in reference to the California submarine canyons, "tributaries, named or unnamed, are relatively rare, though several canyons are like the Monterey in having two or three or four." This statement is seriously in error as applied to California or to any other submarine canyons in areas where there are adequate surveys. Thus Monterey Canyon has at the very least 26 tributaries, and there is little doubt that more-detailed surveys would show more tributaries, as has invariably happened where more-detailed surveys have been made elsewhere. In fact, the tributaries of the best-known submarine canyons, Scripps and Carmel, are comparable in number with tributaries in adjacent land canyons.

Relative to tributaries, students at Scripps Institution have recently been swimming with aqua-lungs along the narrow, steep ridge which separates two of the tributaries of Scripps Canyon and have discovered small steep-sided gullies cut into one side of this ridge. Since there is no surface on top of the ridge on which there could be any gathering ground for the sediment necessary for trubidity currents, erosion by this process could not account for these features.

Estuaries and Canyon Heads

The submergence of rugged land areas cut by canyons should produce deep estuaries. Woodford, however, states (p. 843) ". . . . not a single California canyon heads in an estuary." This is not quite accurate since the canyons of Carmel Bay head in short estuaries (Shepard and Emery, 1941, Fig. 27). Furthermore, many canyons in other parts of the world enter estuaries (Shepard, 1948, Figs. 74, 75, 78, 79). The well-known canyon which heads deep into the estuary of the Congo is most difficult to explain unless, some time in the past, subaerial erosion of a canyon occurred at this place and submarine mass movements and attendant turbidity currents along the old canyon axis have maintained the canyon position. Certainly the great deposition at the mouth of the Congo would have prevented the excavation of a canyon across the broad shelf at this particular place.

The absence of estuaries at the heads of most canyons is by no means surprising if the canyons were cut in the remote past and have been maintained by slides and turbidity currents (Shepard, 1951b). Presumably, ample time has existed for the straightening of the coasts by a combination of waves attacking headlands and streams filling estuaries.

Deep Gorges in Hard Rock

Some of the advocates of submarine erosion have considered that a few deep canyons cut in firm rock are subaerial in origin, and yet there is ample evidence that representative canyons the world over are cut into rock, some of it being known to consist of granite and other hard crystalline types. An examination of the evidence shows that it is virtually impossible to separate these rock-walled canyons from those cut in alluvium or other soft material (Shepard, 1948, p. 209–229). If we consider how canyons might develop under water by landslides and by their attendant turbidity currents (no other process appears to be capable of producing these currents), we can reasonably start with a slope having a mantle of sediments. Let us assume that slides occur on this slope, and valleys like those of the delta fronts result. Since the exploration of submarine canyons has shown that rock commonly lies at relatively slight depths below this sedimentary mantle, it can further be assumed that the sliding and the production of sediment for turbidity currents would continue until the underlying rock was exposed. The rock on this new surface would obviously be much less likely to slide than the overlying sediment. As a result, slides

on other portions of the slope would become relatively more important so that eventually there would be a rock surface with little or no sediment to allow canyon cutting into the underlying rock. No such slopes have been discovered which suggests that deposition on the slopes is, in general, keeping pace or exceeding slumping. Therefore, it seems likely that the canyons were cut by a process such as stream erosion where the water would tend to concentrate along the initial depressions.

Canyons Related to Large Land Rivers

Woodford (p. 843) refers to the "... failure of sea and land valleys to join." If the canyons had been submerged recently, one could expect a close connection between most of the land and sea valleys. If the canyons were sumberged in the remote past, however, there would be no particular reason why present-day rivers should enter the sea directly opposite submarine canyon heads. Actually many of the large rivers have large submarine canyon continuations, as for example the Congo, the Columbia, the Mississippi, the Niger, and the Indus. It is particularly significant that the canyon off the Mississippi appears to have a buried extension, determined by geophysical prospecting, which connects with the abandoned and deeply submerged Pleistocene channel of the Mississippi (Fisk, 1944). The relation of all the main valleys of southern Washington —the Columbia, Willapa, Chehalis, and Quinault rivers—with adjacent submarine canyons can be no coincidence.

The relation of the large river mouths to large submarine canyon heads may constitute a serious obstacle to the turbidity-current hypothesis. Evidence shows that large rivers build out submarine and sublacustrine slopes wherever these streams debouch near such slopes. Accordingly, these areas should be the least likely to have canyons cut by submarine processes. The canyon of the Congo, cut deep into the estuary, is a serious problem, as Woodford has recognized, unless one assumes that the river originally cut this canyon and that after submergence it has been maintained or perhaps recently reopened by a great slide along the old filled gorge.

Submarine Canyons, Gradients and Nickpoints

Woodford is apparently much impressed by the contrast between the longitudinal profiles of the submarine canyons and those of land valleys. He considers that the nickpoints which occur where the canyons approach the shore are proof that the latter were not cut by subaerial erosion. One can certainly agree with him that the simple submergence of a canyon would fail to produce a nickpoint along the valley at the temporary position of the shore line. However, this is an over-simplification of the problem. If the canyons were cut in the remote past and have been submerged over a long period, the nickpoint could be explained by the building of a delta in the drowned estuary out to the present shore line, but leaving the canyon unfilled outside, or by the fill and cut which took place in the submarine canyon following the submergence.

A point which Woodford neglected to mention in his discussion of nickpoints is what happened to the Monterey Canyon as the result of the lowered sea levels of the glacial stages. Unless he believes that the canyon was cut subsea entirely since the last glacial stage, which is most unlikely because of the huge dimensions and the rock walls of the canyon, the lowered sea level should have increased the gradient of the Salinas and caused active cutting into the heads of the pre-existing canyon. This would have given it a subaerial head which, according to Woodford, should have lacked a nickpoint. The subsequent rise in sea level in any case must have redeveloped the nickpoint so that Woodford's submarine origin for the present submarine canyon head from this point of view is no better than the idea of original subaerial excavation.

The discrepancies in gradients between submarine canyons and stream valleys in general, such as those which cut the California coast range, require further consideration. If the coast had been emergent long enough down to the bottom of the continental slope to allow the development of a graded profile and if the submergence had been rapid and recent, one should find the land canyons with gradients continuous with those of the submarine can-

yons. However, there is no indication that any of these conditions has existed. A relatively short exposure of portions of the continental slope would fail to get the canyons into adjustment with the upper portions. Also the remote submergence would allow the streams in the upper portion to develop a profile completely out of line with that beneath the ocean. Many types of gradient could exist in the canyons now on the sea floor depending on the nature of the rocks, the length of time exposed, and the extent to which the gorges are filled with sediment.

Evidence of Submergence

In the rejection of the hypothesis of subaerial erosion most authors seem to overlook the abundant evidence of large-scale submergence which exists along the borders of continents. If the continental margins have been submerging over a long period of time and if, as is now demonstrated, there is a mechanism for keeping open the ancient river-cut canyons of relatively steep gradient, the chief objection to subaerial erosion seems to have been removed. The present article is not the place to deal completely with the evidence of submergence, but it is easily provided for portions of the east, south, and west coasts of the United States as follows:

(1) The deep Standard Oil borings in Cape Hatteras (Swain, 1947) have revealed terrestrial formations at depths of 6500 feet.

(2) The numerous deep drillings into the Mississippi Delta have yielded shallow-water and terrestrial formations at many thousands of feet depth (Lowman, 1949).

(3) The drillings at the head of Monterey Canyon (Woodford, 1951, p. 835–838) show some thousands of feet of sediments, apparently largely shallow marine or terrestrial in origin.

It does not seem unreasonable that at some time during the past the margins could have been sufficiently emergent to have allowed canyon cutting. Can it be maintained on the one hand that landslides and turbidity currents are incapable of keeping open ancient canyons and on the other than these same processes can produce the canyons independently? Surely it requires much less energy to maintain preexistent gorges than to excavate new gorges out of solid rock.

Turbidity Currents as Erosive or Transporting Agents

There is no longer any doubt that some agency, such as turbidity currents, transports great quantities of sediment out along the canyon axes and presumably carries the sediments out over the basins beyond the canyon terminations. The demonstration of transporting powers does not constitute a demonstration of erosion. For example, the lower Mississippi River is transporting enormous quantities of sediment into the sea, but it is not eroding its bed in the true sense. It is simply shifting sediment seaward which was originally eroded by headwater streams with higher gradients. Similarly, turbidity currents may be merely the transporting agents of material provided by landslides. Ericson, Ewing, and Heezen suggest that erosion is indicated in the Hudson Canyon because of the discovery of chalk pebbles, presumably from Eocene beds outcropping up-canyon. Landsliding from the canyon walls, or even on the floor, would account for the presence of these pebbles. Similar slides have been discovered in the exploration of California submarine canyons. In fact, it is these slides which appear to be responsible for the turbidity currents. They stir the sediment into suspension and thus provide the motive power.

One looks in vain for evidence that the turbidity currents actually erode. For example, they must be set up on steep delta fronts where slides are not uncommon, and yet these delta fronts are actually being built forward rather than eroded. Even during the course of a slide, deposition can take place directly in front of the slumped material as shown by Woodford (1951, Fig. 8). Nor are these slides on delta fronts producing net erosion since the deposition which follows more than offsets any temporary deepening.

The inability of turbidity flows to erode is further suggested by finding cores on steep

portions of canyon floors with undisturbed fine-grained deep-water formations overlain by coarse sands (Shepard, 1951a). This indicates that even in the places of high gradients the flows have been incapable of cutting away the soft underlying muds. This finding is entirely in agreement with the reports by Migliorini (Kuenen and Migliorini, 1950) that delicate fossil impressions on the surface of shales underlying the coarse turbidity current deposits are left intact indicating an extremely gentle action of superimposition. The observation of turbidity currents in tanks similarly indicates a suspension moving through the lower portion of a water body without particularly disturbing the underlying surface. The suspension is easily deflected off the bottom and apparently shows no tendency to erode.

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CONTENTS

	Pages
Abstracts of papers submitted to the November meeting in Detroit, Mich., November 8–11, 1951 (Geological Society, Mineralogical Society, Paleontological Society, Society of Vertebrate Paleontology, Society of Economic Geologists)	1419–1494
Abstracts of papers submitted to the April meeting in Los Angeles, Calif., March 23–24, 1951	
Cordilleran Section of the Geological Society	1495–1516
Mineralogical Society	1517–1520
Pacific Coast Branch of Paleontological Society	1521–1524
Seismological Society	1525–1530
Abstracts of papers submitted to meeting of Rocky Mountain Section in Rapid City, South Dakota, April 13–14, 1951	1531–1544
Abstracts of papers presented at the meeting of Section E, AAAS, in Philadelphia, Penna., December 27–28, 1951	1545–1562
Index to Volume 62 (July–December)	1563–1578

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ABSTRACTS OF PAPERS SUBMITTED TO THE NOVEMBER MEETING IN DETROIT, MICH., NOVEMBER 8-11, 1951

ABUNDANCE OF ELEMENTS IN IGNEOUS ROCKS AND IN METEORITES. A REPORT OF PROGRESS

L. H. Ahrens
Mass. Institute of Technology, Cambridge, Mass.

Several rarer elements (Li, Rb, Cs, Cu, Ag, Ga, Pb, La, Y, Nd, Sc, V, Co, Cr, Sr, Ba, Zr, and F) have been determined quantitatively in common igneous rock types (granite, diabase, basalt, gabbro); a few (Rb, Sc, and Li) have been determined in common silicate meteorites (chondrites). Spectrochemical procedures have been employed for all determinations.

On the basis of these analyses new abundance values are given for the above elements in igneous rocks and in meteorites. Several of the new abundance values are the same as, or differ only slightly from, published values; a few show significant differences: for example the relative abundance of Sr and Ba in igneous rocks and the abundance of Rb and Sc in meteorites.

In order to reduce systematic errors in the analyses as far as possible, all have been calibrated in terms of two standard rocks: one of diabase and one of granite. Each has been analyzed by several analysts.

Abundance calculations on igneous rocks have been made on the basis of 2 parts granite + 1 part diabase (or compositional equivalent) as having about the same composition as the mean igneous rock composition on the earth's surface.

The quantitative spectrochemical analyses have been carried out mainly by Lorraine G. Gorfinkle, Margaret M. Kearns, R. H. Seraphim, and William H. Pinson (meteorites).

IONIC RADII OF THE ELEMENTS

L. H. Ahrens
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Of the two sets of ionic radii in common use—(1) Goldschmidt and (2) Pauling—those of Goldschmidt are usually employed by crystallographers, mineralogists, and geochemists. Their use in preference to the other set is not supported by the relationship between ionic radius and ionization potential.

Within an isoelectronic sequence, ionic radii vary regularly with ionization potential. This is particularly well developed when Pauling radii are employed and is interpreted as strongly supporting their use in preference to those derived purely from measured interatomic distances. Other regularities between radius and ionization potential, and between radius and charge, are also well developed when Pauling radii are used.

Deviations by measured (Goldschmidt) radii can usually be explained by:

(1) an assumed radius of 1.32 A for O^{2-} as too low,

(2) significant polarization of O^{2-} by cations of high polarizing power, and

(3) some inaccuracies in interatomic distance measurements.

Radii in the isoelectronic sequence, $Li^{+} - Be^{2+} - B^{3+} - C^{4+} - N^{5+} - O^{6+} - F^{7+}$ have been revised on a basis of a radius of 0.68 A for Li^{+} rather than 0.60 A as used by Pauling.

Hitherto unknown radii for W^{6+}, Po^{6+}, Re^{7+}, Tc^{7+}, and At^{7+} have been determined graphically by means of the well-developed regularities between ionization potential, charge, and radius.

QUANTITATIVE SPECTROCHEMICAL ANALYSIS OF SILICATES: A SCHEME OF ANALYSIS

L. H. Ahrens
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An analytical scheme of DC arc quantitative spectrochemical analysis of silicates (silicate rocks, common rock-forming minerals, sediments, and silicate meteorites) is described, in which an attempt is made to combine the advantage of speed of semiquantitative general methods with the accuracy of time-consuming specific methods.

Elements frequently detectable in natural silicates are grouped according to their properties significant for spectrochemical analysis, as follows;

(1) alkali metals (Li, Na, K, Rb and Cs)
(2) the volatile group (Ga, Pb, Tl, Ag, Cu, Zn, Sn and Ge)
(3) the involatile group (V, Ni, Co, Cr, Sc, Zr, Sr, Ba, Y, Nd, La and Mo)
(4) F

Elements in each group are determined in a single operation. A separate internal standard is used for each group. The major constituent elements, other than Na and K, may be determined in a separate operation.

The presence of a significant concentration (> 1–2%) of Na + K in almost all naturally occurring silicates has played a major role in developing the analytical scheme.

For most constituents, standard deviations fall between 2.5 and 8 per cent. The determination of fluorine is somewhat less accurate as its standard deviation is about 15 per cent.

The procedures outlined in the analytical scheme have been employed by workers in the Cabot Spectrographic Laboratory, M. I. T., for the quantitative determinations of several constituents (major and minor) in several hundred silicate specimens, including meteorites.

SALITE AND ACTINOLITE AT IRON MOUNTAIN, MISSOURI*

Victor T. Allen and Joseph J. Fahey
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Salite, actinolite, dolomite, and fluorite at Iron Mountain, Missouri, are reported for the first time. Salite, an intermediate pyroxene of the diopside-hedenbergite series, occurs in a skarn formed by the action of iron-bearing solutions on andesitic lava of Precambrian age. The salite occurs as grayish-green columns up to 10 inches long; it has the following chemical composition and optical properties: SiO_2, 52.76; Al_2O_3, 1.12; TiO_2, 0.16; Fe_2O_3, 1.73; FeO, 8.92; MnO, 0.47; CaO, 20.48; MgO, 13.43; Na_2O, 0.35; K_2O, 0.05; H_2O, 0.45; $\gamma = 1.715$; $\alpha = 1.695$; $2V = 60°$; positive; $Z \wedge C = 45°$; density, 3.350. At somewhat lower temperature salite was locally changed to actinolite, which has previously been called amphibole or tremolite, but optical properties of numerous grains fall within the range of actinolite with $\gamma = 1.645$; $\alpha = 1.625$; $Z \wedge C = 15°$. The iron garnet, andradite (N = 1.88), replaces actinolite, and euhedral, zoned dodecahedrens contain relict fibers of the actinolite. Calcite and quartz replace actinolite and are cut by veins of hematite. Purple fluorite occurs in quartz, but is not in contact with hematite, so its age relation to hematite is unknown. A pink carbonate, having the color of rhodochrosite, occurs in veins cutting the andesitic lava, but it contains only 1.45 per cent MnO and has the optical properties of dolomite with $\omega = 1.685$. Thus, doubt is raised concerning the rhodochrosite and manganocalcite reported in 1895 from this deposit.

* Publication authorized by the Director, U. S. Geological Survey.

POSSIBLE DIATREME IN SYRACUSE, NEW YORK

Earl T. Apfel, James E. Maynard, and Louis W. Ploger
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A pipelike mass of igneous rock recently partly exposed in Syracuse, New York, consists principally of pebbles, cobbles, and boulders up to 10 feet long of Paleozoic sedimentary and Precambrian cyrstalline rocks in a matrix of ultra-basic igneous rock and in a soil apparently derived from this rock. A corelike mass of dark greenish-gray peridotite lies within the zone containing the abundant inclusions. Dikes in the rock indicate more than one episode of igneous activity. Hydrothermal alteration has apparently serpentinized and decomposed a considerable part of the igneous rock, and the included rock fragments also show alteration.

The youngest country rock in which the igneous mass occurs is the Camillus formation (Silurian). Middle Devonian fossiliferous rocks are the youngest thus far identified among the cobbles and boulders included within the peridotite. These rocks once lay not less than 500 feet above their present position. The eruption is thus dated as Middle Devonian or later. Conclusive evidence of explosive action has not yet been identified; the designation of the mass as a diatreme is therefore uncertain. Previous to exposure by excavation the mass had a drumlinoid form with a thin veneer of till.

STATUS OF SUMMARY COAL-RESOURCE SURVEYS, NOVEMBER 1, 1951

Paul Averitt
U. S. Geological Survey, Washington, D. C.

Summary coal-resource studies completed or in progress during 1951 show a continuation of the trend toward a moderate reduction of the older coal-reserve estimates. More significantly, however, the newer estimates provide for the first time a breakdown of the coal-reserve figures into categories according to the thickness of the beds, thickness of the overburden, and the relative abundance and reliability of the information available for making the estimates. Extrapolating from the small amount of classified summary reserve data now available it appears that roughly 15 per cent of the total estimated reserves in the United States can be regarded as measured reserves in beds 28 inches or more thick under less than 2000 feet of overburden; that an additional 15 per cent can be regarded as indicated reserves within the same limits of thickness and depth below the surface; and that the remaining 70 per cent includes inferred reserves, reserves in thin beds, or reserves 2000 to 3000 feet below the surface.

A consideration of this latter category, representing 70 per cent of the total reserves, suggests that it includes as inferred a fairly large percentage of coal in the thicker beds, which for lack of detailed information cannot be appraised quantitatively. The percentage of measured and indicated reserves in the thicker beds under less than 2000 feet of overburden will therefore increase as additional geologic and exploratory work on coal is completed.

PHOSPHATE MINERALIZATION AT BOMI HILLS AND BAMBUTA, LIBERIA, WEST AFRICA

J. M. Axelrod, M. K. Carron, C. Milton, and T. P. Thayer
U. S. Geological Survey, Washington, D. C.

An interesting suite of iron phosphate minerals formed by biogeochemical processes has been found at Bomi Hills and at Bambuta in western Liberia. The phosphates at Bomi Hills form bouldery aprons on the slopes below two prominent cliffs and occur in caves and open fissures in cliffs of high-grade iron ore where they were formed by the interaction of bat dung, or substances derived

from it, with exposed iron oxide. The substances thus formed include strengite and its dimorph, phosphosiderite; a member of the rockbridgeite group (formerly included with dufrenite); and, most noteworthy of the suite, a complex substance, or possibly mixture of substances, apparently closely related to leucophosphite, described by Simpson (1932) from Western Australia.

The evidence, admittedly not conclusive, for regarding the Australian and African substances as constituting a mineral species is considered; their provisional acceptance as such rests on their similar and unique x-ray diffraction patterns, and essentially similar chemical composition—namely, potassium-ammonium-ferric hydrous phosphate. The paragenesis of the several phosphate minerals is discussed, based largely on petrographic study of the various specimens, with identification of the crystalline phases by x-ray diffraction patterns.

NEW TEKTITE AREAS IN TEXAS*

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Bureau of Economic Geology, The University of Texas, Austin, Texas

Tektites have been collected for many years by the residents around Muldoon, Fayette County, in a 5- by 10-mile area. Recently two tektites have been found in Gonzales County. The glass of some of the tektites (rough specimens) is light olive-brown (5Y 5/6) and highly translucent, whereas that of the bediasites (Barnes, Univ. Texas Pub. 3945, p. 477–656, 1940) is only feebly translucent on thin edges. The refractive index of the glass (3 specimens) is 1.489 ± .003, which is the average of the refractive index of moldavites. Some of the Muldoon tektites resemble moldavites more closely than they do any other tektite group. The distribution of tektites in Texas suggests that they are weathering out of the upper part of the Upper Eocene Jackson formation.

The chemical composition of tektites and the presence of included lechatelerite particles suggested to Barnes that tektites are fused sediments and therefore of terrestrial origin. However, the two periods of fusion exhibited by australites were recognized as being incompatible with a terrestrial origin. It is now suggested that tektites are derived from a celestial body, destroyed by collision, which contained sedimentary and other rocks similar to those on earth. Glasses formed from such a body would have a wide range in composition and could include supposedly nontektite glasses, such as Libyan desert glass, and questioned tektite glasses, such as the americanites.

STUDIES OF METAMICT MINERALS. (I): METHODS AND PROCEDURES†

Joseph Berman
U. S. Geological Survey, Washington, D. C.

Review of the literature reveals much confusion in the identification of metamict minerals and in interpretation of results obtained by x-ray powder studies. The need for standard methods of studying these minerals is urgent.

On the basis of x-ray powder patterns it is ascertained that many minerals containing radioactive elements show various degrees of "metamictization." Reproducible powder patterns are obtained after ignition of these minerals in certain gases under controlled temperatures. The current practice of heating a sample in a crucible over an open flame may lead to misinterpretation of resultant patterns.

Our studies have indicated that ignition of the noncrystalline specimens results in randomly oriented crystallized material. None of our samples recrystallized as single homogeneous crystals, although this phenomenon has been reported for gadolinite. The results also indicate that different gases have a marked influence on crystallization and on dissociation of some material.

* Published with permission of Director, Bureau of Economic Geology, The University of Texas.
† Approved by Director of U. S. Geological Survey.

The apparatus used for heating consists of a tube furnace that can be set up for heating in air or in any other atmosphere. The samples are first crushed and then heated at temperatures below their fusion points for a short time both in air and in uncontaminated helium. It was found that both helium and commercial nitrogen, which for a time was used as the inert gas, contain sufficient water to oxidize the specimen being heated.

The resulting x-ray powder patterns are strong with sharp diffraction lines indicating good crystallinity after ignition. Preliminary data on allanite, brannerite, davidite, fergusonite, samarskite, thorite, and zircon are given.

ROBINSONITE, A NEW LEAD ANTIMONY SULPHIDE

L. G. Berry, Joseph J. Fahey, and Edgar H. Bailey
Queen's University, Kingston Ontario;U. S. Geological Survey, Washington, D. C.; U. S. Geological Survey, Los Gatos, Calif.

Triclinic; $a = 16.51$A, $b = 17.62$A, $c = 3.97$A, $\alpha = 96°04'$, $\beta = 96°22'$, $\gamma = 91°12'$. Slender prismatic [001], striated [001]; also massive, fibrous to compact. Cleavage, not observed; fracture, irregular; brittle, H 2½–3. Measured specific gravity, 5.27 (artificial crystals), 5.20 (natural fragments), 5.34 (artificial fused material). Composition and cell content, $7PbS.6Sb_2S_3$, with calculated specific gravity, 5.40. Strongest x-ray powder lines, in Angstroms: 4.08(6), 3.97(6), 3.41(10), 3.19(6), 3.04(6), 2.74(5), 2.68(5).

Occurs as a primary mineral with pyrite, sphalerite, stibnite, and boulangerite as small pieces in oxidized ore bodies at the Red Bird mine, Pershing County, Nevada.

PETROLOGY OF THE GUFFEY-MICANITE REGION, COLORADO

James E. Bever
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The Guffey-Micanite region, in southeast Park County and in north-central Fremont County, Colorado, is underlain chiefly by Precambrian rocks, bounded, except on the south, by extrusive igneous rocks of Tertiary age. The Precambrian rocks include: (1) the Idaho Springs formation, which consists of mica schists and gneisses, sillimanite schists and gneisses, and lime-silicate rocks, all of meta-sedimentary origin, (2) lenses and layers of hornblende gneiss and amphibolite that may represent metamorphosed gabbros or basalts; (3) several bodies of granite, which may belong to more than one intrusive period; (4) granitic pegmatites, related to the granite, containing the accessory assemblage: beryl (including golden beryl), garnet, apatite, columbite, schorl, Fe-Mn phosphates, magnetite, bismutite, beyerite, cordierite-pinite, sillimanite, monazite, and uranothorite (?); (5) migmatite formed locally by intense injection of granitic material into rocks of the Idaho Springs formation. In addition to the pegmatite minerals, feldspar, sheet and scrap mica, beryl, and columbite, other minerals of economic significance include galena, sphalerite, scheelite, chalcopyrite (with anthophyllite), and sillimanite.

STRUCTURES IN ICE WEDGES OF NORTHERN ALASKA

Robert F. Black
U. S. Geological Survey, Washington, D. C.

Minute structures, generally considerably smaller and more complex than structures in glacial ice, were found in ground ice during petrofabric study of ground-ice wedges near Barrow, Alaska. Not all can be explained easily. However, results supplement concurrent research on ground contraction, temperatures, and composition and provide corroborative evidence for Leffingwell's contraction hypothesis of origin of ice wedges.

All wedges have myriad bands of air bubbles and inclusions of organic material and silt, sand, and gravel, which in most wedges produce marked foliation subparallel to the sides. Other bands crisscross within the wedges. Most air bubbles and inclusions are elongated vertically regardless of orientation of the band in which they are found.

All wedges show marked development of one or more microscopic growth fabrics in which *c* axes are oriented about normal to cooling surfaces. The best-developed fabric, presumably resulting from recrystallization under pronounced temperature gradients and considerable lateral compression, is fan-shaped and conforms roughly to the shape of the wedge. Other fabrics are produced by growth of hoar and ice crystals in contraction cracks and tension fractures.

Most wedges also show one or more deformation fabrics superimposed on growth fabrics, or vice versa. Individual grains respond to stress by strain, reorientation (apparently in part to permit slipping on the basal pinacoid or rolling around the *c* axis), fracture, granulation, and recrystallization. Movement within wedges is indicated by granulated and recrystallized grains, tension fractures, shear planes, offset bands of air bubbles and inclusions, dragged sediments on sides of wedges, and surface ridges.

ORIGIN OF OFFSHORE BARS

Sankey Lee Blanton, Jr.
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Offshore bars are linear sand barriers, roughly parallel to the coast line and generally disconnected from the mainland. They are composed of two parts: a lower aqueous and an upper aeolian deposit. Bars off the coast of North Carolina are genetically related to embayments and streams on the mainland.

Most offshore bars lie on the eastward sides of continents and are directly in the paths of hurricanes or storms during which sea level is temporarily elevated. Once formed, these bars are reshaped by wind, longshore and tidal currents. Because the earth rotates to the east there is a tidal distortion which causes the inflow of tidal waters to be more rapid than the outflow. The lagoonal sides of the bars are the more stable sides, as wind and currents are less active there than on the seaward faces. It is demonstrated that the sediments that control the existence of the bars are immediately derived from the sea.

Offshore bars are special types of bay-mouth bars produced by the submergence of coasts where there is an abundance of sand-sized particles in disequilibrium with the profile of optimum wave movement. They originate seaward from embayments and grow laterally in both directions. Depending upon the profile of optimum wave movement they will either be destroyed in place or be abandoned with a new set of offshore bars developed seaward in front of major inlets.

MISSISSIPPIAN SCOLECODONTS NEAR CHARDON, OHIO

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Excellently preserved scolecodonts have been found in the Cuyahoga strata of Kinderhookian age in the vicinity of Chardon, Ohio. Seven genera and 14 species are tentatively identified from the Orangeville and Sharpsville formations, the two lowest subdivisions of the Cuyahoga group. The most common genus is *Nereidavus* which has been identified from shale samples from both of these formations. Representatives of the other six genera were found only in the Orangeville formation.

In 1879, Hinde named and described two genera and two species from the Lower Carboniferous limestone at Cults, in Fifeshire, Scotland. As far as the writer has been able to determine, no other Mississippian scolecodonts have ever been reported.

SYNTHETIC GRANITES AND THEIR MELTING BEHAVIOR UNDER HIGH H_2O PRESSURES

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Mixtures of $NaAlSi_3O_8$, $KAlSi_3O_8$, and SiO_2 have now been examined as to their melting behavior at 4 isobars, 500, 1000, 2000 and 3000 kg/cm² pressure of water vapor. At each pressure the addition of SiO_2 to the feldspar solid solution series induces the expected further lowering of melting temperatures. The minimum melting temperature of the binary feldspar series is reflected in the ternary compositions as a minimum temperature on the boundary curve between the field of quartz and that of feldspar solid solutions. These minimum-melting mixtures are synthetic alkali granites.

The temperature of the minimum decreases with increasing pressure of water vapor, owing to the increased solubility of water in the liquid phase, but, whereas the first effects of increasing pressure are very marked, these diminish rapidly, and the difference between the value for 2000 kg/cm² and that for 3000 kg/cm² is only about 5°, the actual temperatures being 675° and 670° respectively. Moreover, the composition of the minimum moves with increasing pressure toward a somewhat lower quartz content.

Some of the consequences of these observations on theories of the origin of granite will be discussed.

PERMO-PENNSYLVANIAN ZEUGOGEOSYNCLINE OF COLORADO AND NORTHERN NEW MEXICO

Kenneth G. Brill, Jr.
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The Belden formation appears to cross time lines. It is Morrowan and Desmoinesian and by inference is probably also Atokan. The first Belden deposits in the trough were in northwestern Colorado; from here the deposition of dark shale progressed southward through the trough.

Strata containing Atokan Fusulinellas seem to overlie the Kerber (Belden) formation in Huerfano Park, Colorado. These strata, which are equivalent to the Clastic member of the Sandia formation, were deposited in a sea that advanced northward into the trough.

Marine deposition of Cherokee age (*Fusulina-Wedekindellina* zone) is continuous the length of the trough. This was the only time that the trough was completely flooded by the sea. Specific differences in the Cherokee microfauna north and south of Huerfano Park suggest that an ecological barrier existed here. The equivalent of the Gray limestone member of the Madera formation rests on the Belden formation in south-central Colorado. A sandy limestone zone in southern Colorado and New Mexico is believed to be equivalent to the Jacque Mountain limestone of the Gore area. This limestone is Cherokee in age. The Jacque Mountain limestone and its equivalents have been used as a datum in correlating the Pennsylvanian strata in the trough from northern Colorado to northern New Mexico. A lithofacies map of the Pre-Jacque Mountain strata shows the lithologic associations in the trough. Reptile bones of Wolfcamp age occur in the upper red beds near Salida, Colorado.

STUDIES OF RADIOACTIVE COMPOUNDS: IV—PITCHBLENDE FROM LAKE ATHABASKA

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Geological Survey of Canada, Ottawa, Ontario; University of Toronto, Toronto, Ontario

Chemical analyses of six specimens of pitchblende from Lake Athabaska gave a range in U^6/total U from 17.4 to 85.0 %. With increasing U^6/U the specific gravity decreases from 8.20 to 4.10, the luster becomes dull, and the mineral loses its hard, compact, and brittle aggregation and assumes a

soft, earthy form. Thus in a general way the physical properties are indicative of the degree of oxidation.

Specimens relatively low in U^6 gave sharp x-ray powder photographs. With increasing U^6/U, back reflections became weak and diffuse, then low-angle reflections became diffuse, and finally with $U^6/U = 85.0$ % no pattern was obtained. The corresponding cell edges decreased from 5.45 kX for $U^6/U = 17.4$ % as compared to 5.46 for synthetic UO_2, to 5.39 for $U^6/U = 78.5$ %. Therefore in the six specimens the quality of the x-ray pattern and the cell sizes are related to the degree of oxidation.

After heating for half an hour in vacuum the patterns were sharper, and the cell edges decreased to 5.43 for synthetic UO_2, and to a minimum of 5.38 for the more highly oxidized specimens. In specimens with U^6/U about 50 per cent, another oxide, possibly U_3O_4, also formed; this was replaced by U_3O_8 when U^6 dominates over U^4.

Heating for 5 minutes in air oxidized those specimens with U^6/U about 50 per cent to U_3O_4, while those with a higher or lower U^6/U ratio were oxidized to U_3O_8. The cell edges of U_3O_8 increased with increasing availability of U^6 in the untreated material.

ISOTOPIC COMPOSITION OF LEAD AND THE AGES OF MINERALS IN A PRECAMBRIAN GRANITE

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Techniques have been devised for the analysis of microquantities of lead and uranium in granitic materials using isotopic tracers. The general method consists of equilibrating known microamounts of lead or uranium highly enriched in a single isotope with known amounts of the sample, chemically isolating the element, and measuring the change in the isotopic composition of the tracer. Chemical procedures, which progressed from a macro- to a microscale, and surface-ionization techniques in a mass spectrometer of a very high sensitivity were used. The concentration and isotopic composition of lead and uranium in mineral separates of a Canadian granite have been studied. These data have given the lead-uranium and lead-lead ages of the minerals. The data have also given the isotopic composition of a nonore lead of known Precambrian age, and the isotopic composition of nonore uranium.

INFOLDED MID-ORDOVICIAN LIMESTONE ON PRECAMBRIAN NORTH OF PEEKSKILL, NEW YORK AND ITS BEARING ON THE REGION'S OROGENY

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In a new road cut north of Peekskill, New York, on U. S. Highway 9, a gray limestone, partly recrystallized to a white marble, contains rounded cystoid fragments and abundant grains, pebbles, and boulders of metamorphic and plutonic rocks. It rests on an irregular erosion surface of the Precambrian basement and is tightly infolded in it. Four miles to the southwest, on the west side of the Hudson River at Tompkins Cove, similar, carbon-rich gray limestones with similar cystoid fragments and streaks of coarse grains of quartz and metamorphic materials lie at the base of the "Hudson River slates", essentially conformable with the underlying thick carbonate sequence ("Wappinger limestone"). Between these two points, the gray limestone and the slate series above it transgress onto the Precambrian core of the New York Highlands, cutting out what Berkey estimated to be 1000 feet of dolomites and limestones.

One and one third miles to the northeast on Conopus Creek, the same infolded limestone (here wholly recrystallized and called "Grenville" on Berkey's map) contains also rounded pebbles of

coarse-grained dolomite and blocks of a coarse quartzite. This shows that considerable warping and erosion preceded the transgression of the gray limestone and the slate sequence.

The demonstration of this overlap relation may help to explain the highly irregular contact of the slate, carbonate, and quartzite formations with the Precambrian which prompted Robert Balk to draw an almost uninterrupted fault line clear around the highly irregular border of the Highlands' Precambrian on his "Geological Map of the vicinity of Dutchess County, New York" (1936). It appears probable that the stratigraphic relations of the Cambrian and Ordovician formations around the New York Highlands were comparable to that of the formations of similar age around the Ozark Uplift. But, the Highlands have later suffered intense orogenic compression. The disharmonious behavior of the sediments has produced effects that simulate faulting.

URANIUM DEPOSITS, BEAVERLODGE AREA, SASKATCHEWAN, CANADA

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The Beaverlodge uranium deposits are located on the north shore of Athabaska Lake, Saskatchewan, Canada. The deposits occur in Proterozoic rocks. The Tazin series consisting of highly altered quartzite, shale, arkose, etc., is overlain unconformably by the Athabaska series consisting of conglomerate arkose and intercalated basalt and andesite flows. Two strong northeast–southwest faults, the St. Louis and the Crackingstone, are recognized. It is inferred that the many tensional fractures and shattered zones in which the uranium mineralization is found are principally related in many instances to stresses developed by movements along these faults.

In an area of approximately 120 square miles in the Beaverlodge district, many hundreds of isolated occurrences of pitchblende have been noted. At present, one deposit—the Ace—is being prepared for production. Five deposits—Eagle, Martin, Nicholson, Rix, and Nesbitt-Labine—are being tested underground. Surface exploration and diamond drilling suggest that an additional five deposits—Cinch, Amax, Pitchore, and Fishhook—probably warrant exploration underground.

The pitchblende in the majority of the deposits occurs as plates and thin veinlets in irregular discontinuous tension fractures or as scattered small masses and local disseminations in wide breccia zones. The host rocks are usually impregnated with red, dusty hematite. Pitchblende is generally associated with pyrite and chalcopyrite and minor amounts of minerals containing cobalt, nickel, lead and zinc. The nonopaque gangue minerals with the pitchblende comprise calcite, chlorite, and quartz.

INFLUENCE OF MINOR GEOLOGIC STRUCTURES ON DAM CONSTRUCTION

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Many of the foundation problems of dam construction result from the minor geologic structures contained in the foundation rocks. Low-angle minor thrusts, minor shear zones, ruptured contacts, weathered bedding planes, weathered open and sheeted joints, spheroidal weathering, and clay partings are common structural flaws that may introduce problems. Structures of this kind all too frequently escape detection by the small-diameter core drillings, or, if they are found, their orientation and significance may not be disclosed. Their oversight in the planning stage may involve modifications in design, changes in construction procedures, increases in quantities, delays in construction schedules, and lead to claims and change orders. Therefore, discovery of minor geologic structures is a paramount objective of dam-site investigations. The advancements made in exploratory methods in recent years have been pointed expressly at this objective and include such noteworthy developments as the large-diameter calyx drill and the new type core barrels by means of which high core recoveries may be obtained with small-diameter drills in soft, friable foundation materials.

A recent development is a photographic method by means of which 360-degree photographs of small-diameter bore holes can be taken on 16 mm color film and projected to scale in undistorted form on a cylindrical screen. This development provides a cheap method of obtaining complete photographic records of the minor geologic structures in 3-inch diameter borings and of determining accurately their depth, dimensions, and orientation. Still in the experimental stage, this development gives promise of becoming a major advancement in exploratory methods.

DISTRIBUTION OF INTERMEDIATE AND BASIC IGNEOUS ROCKS IN THE TERTIARY OF WESTERN UNITED STATES

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Tertiary volcanic rocks have been mapped and studied in detail in only a very few places in the western United States. Available information for the southwestern region extending from New Mexico to the Sierra Nevada suggests a definite pattern of volcanic and intrusive succession. Intermediate rocks, chiefly andesites and latites, form an older series which is followed by major granitoid intrusion, mineralization, and subsequent erosion. This series is followed by a later series dominated by rhyolite, latite, and basaltic andesite. Granitoid intrusives in the later series are exceedingly rare, and, though mineral deposits do occur, they are greatly restricted as compared with the earlier series. Both series are older than latest Miocene. Subsequent volcanic activity is greatly restricted in volume and limited almost wholly to basaltic andesite, olivine basalt, and rhyolite. Analyses of the most calcic members of each age group indicate progressive decrease in silica so that the most recent flows may be undersaturated.

In the Pacific Northwest igneous activity was prominent in all epochs of the Tertiary and is dominated by basaltic andesites and basalts throughout the earlier Tertiary. Great floods of olivine basalt of probable Pliocene age make up much of the High Cascades and large areas in south-central Oregon. These were followed by andesites, rhyolites, and basalts, some of post-Wisconsin age. Granitoid intrusive bodies and mineral deposits are almost wholly restricted to the Miocene or older rocks.

CONCERNING THE EURYPTERID *MEGALOGRAPTUS*, AN UPPER ORDOVICIAN ANACHRONISM

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A metabentonite deposit in the upper Elkhorn formation (Richmond subseries, Cincinnatian series, Upper Ordovician) near Manchester, Ohio, has yielded some of the most complete eurypterid fossils known anywhere. The chitinous exoskeletons are preserved in an inflated state, with the chitin still flexible and retaining scorpionid color pattern. Many of the specimens are completely articulated, and some have been largely freed from the matrix. Males, females, and various growth stages are known. The association is typically marine biocoenose with many characteristic upper Richmond marine organisms present.

The general aspect of the organisms is that of exceedingly spinose mixopteroid eurypterids, with very long articulated spines on most anterior legs. The whole body was scaly and porous and generally heavily hirsute, owing to the presence of many sensory bristles. Although referable to *Megalograptus* (based on a eurypterid leg mistaken for a graptolite), the species is new, and a new family is required for the genus. In many respects this is the most primitive eurypterid yet known, although by no means the oldest. No eurypterid approaches the trilobites more closely in organization. It is

at the same time one of the most curiously specialized eurypterids: its body terminated in a horizontally opposable pair of scimitarlike cercal blades beneath the stout telson which itself was capable of considerable vertical movement. Such a protective or copulatory device is unknown among fossils, and the only very similar organisms are the existing earwigs among the insects.

ASSOCIATION OF PERTHITIC MICROCLINE WITH HIGHLY UNDULANT OR GRANULAR QUARTZ IN SOME CALCALKALINE GRANITES

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Perthite is on the whole uncommon in the micaceous calcalkaline granites of New England, Texas, and the Southeastern States. It is usually rare or lacking if quartz is ungranulated and shows only moderate undulance, may or may not be common if quartz extinction is highly undulant, and is never rare if quartz is extensively granulated. The shearing stresses which render quartz extinction undulant and finally granulate the quartz evidently induce or accelerate the unmixing of albite-poor microcline which might otherwise remain indefinitely metastable.

GEOLOGY IN HIGHWAY DESIGN AND CONSTRUCTION: THE PENNSYLVANIA TURNPIKE'S WESTERN EXTENSION

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The Western Extension of the Pennsylvania Turnpike, to be opened in December 1951, is in the Allegheny Plateau geographical province. The bedrock is relatively flat-lying and consists chiefly of sandstones, shales, limestones, coals, and clays belonging to the Pottsville, Allegheny, Conemaugh, and Monongahela groups of the Pennsylvanian Period. Some glacial deposits are present.

The principal problems influencing highway design and construction in this region where cyclothemic stratigraphy is the rule relate to special cut design, slide problems, presence of coal mines, and swamp factors. The Conemaugh shales and clays make the slide problem more serious in Western Pennsylvania, Eastern Ohio, and Northern West Virginia than in most other sections of the Appalachians. In consequence, compound cut slopes are often essential. The prevalence of bituminous coal mines both above and below grade require special drainage, excavation, and "slushing" applications. Glacially filled valleys with high water tables, and thick glacial river terraces pose problems uncommon in the folded Appalachians.

The necessity of deep-cut excavations and the lack of abundant, suitable concrete aggregates and base coarse materials complicate generally difficult design and construction planning.

DRIFTLESS AREAS IN NORTHEASTERN MONTANA

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Four driftless areas in Daniels, Valley, and Roosevelt counties, northeastern Montana, have now been mapped. They cover about 500 square miles and lie at an average elevation of 2800 feet. They are largely restricted to the summits of mesalike remnants of the Flaxville plain that were apparently high enough to project above the level of the surrounding ice. Glacial features such as ice-marginal channels, rectilinear till ridges, lateral moraines, kames, and eskers assist in defining the margins of the driftless areas.

SEDIMENTARY FACIES CHANGES IN COAL STRATA

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Association of certain strata with beds of coal, and the occurrence of such beds in repetitive vertical order has resulted in the establishment of "typical" cyclothems, based primarily upon the fundamental units recognized in Illinois. Both to the east and west of this medial area components of an individual cycle are recognized with greater difficulty. These departures from the ideal cyclothem are responses to primary differences in environmental conditions in part established by the tectonic behavior of the depositional site.

General aspects of variability of depositional conditions in scattered geographic localities are more clearly defined by the bulk lithology of a unit of rocks including several coal cycles, than in lithologic units within an individual cyclothem. The overall sedimentary facies of the large unit can be observed to change laterally as it is traced over an area including several states.

For purposes of illustration the lithologic variation within an interval of strata between two widespread coal horizons has been selected as an example of observed facies change. In some localities gradation between facies is rapid; whereas, in others there is little change between widely separate localities. Individual beds within the large unit often show great variability but they reflect the deviation from the average facies at a selected geographic point. The sedimentary facies of the large unit represents the "normal" condition and, therefore, indicates the nature of the "typical" cyclothem at that locality.

Tracing a finite unit over a wide area demonstrates the variety of conditions under which coal has accumulated. The mapped patterns which emerge lead to an understanding of the environmental-tectonic complex of which coal deposits are a part.

FISH CREEK PHACOLITH, NORTHWESTERN NEW YORK

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The Fish Creek mass is located in the Brier Hill quadrangle, New York. It is steeply plunging, nearly isoclinally folded body with an outcrop area of approximately 12 square miles. The outcrop surface is nearly a cross section perpendicular to the axis of the mass. The main part of the mass is a fine-grained pink alaskite gneiss with local concentrations of melanocratic xenoliths. Medium-grained gray-green trondhjemite, which is regarded as a portion of the alaskite magma contaminated by impure marble, forms a discontinuous border facies. All intrusive contacts observed are with highly metamorphosed Precambrian Grenville series marble. The mass is considered to be a phacolith because: (1) it is generally concordant; (2) it occupies the trough of a syncline; (3) it has a general lenticular cross section; and (4) it appears to have resulted from the consolidation of magma that was syntectonically intruded. This mode of emplacement is inferred because of marked thickening on the plunging nose of the mass and the presence of sheetlike xenoliths (many have observed minimum dimensions along their strikes and parallel to their dips that are 5000 and 500 times their thicknesses) within the alaskite. The lack of a systematic spatial arrangement within the Fish Creek mass of alaskite that is apparently undeformed, alaskite that has a marked cataclastic texture, and alaskite that has been completely recrystallized is thought to be corroborative, as this feature appears to be explained more readily as the result of deformation during the consolidation of the magma than by subsequent deformation of the solid rock.

HAWAIIAN SWELL, DEEP, AND ARCH AND THE SUBSIDENCE OF THE HAWAIIAN ISLANDS

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Fathograms, which given an integrated picture of the bathymetry around the Hawaiian Islands, were obtained during the Scripps-Navy Expedition to the Mid-Pacific, 1950. The Hawaiian Islands are superposed on a broad low rise, the Hawaiian Swell, which is about 600 miles across. Along the base of most of the Hawaiian Islands is a depressed zone—the Hawaiian Deep. Outside of the Deep and to the east of the Oahu-Hawaii region there is a large arcuate arch, the Hawaiian Arch, which is 200 miles across and at least 600 miles long. The Hawaiian Islands are fringed by deep terraces to depths as great as 700 fathoms.

Three possible origins of the Hawaiian structure are examined: (1) it may be related to strike-slip faulting along which there has been a great effusion of lava; (2) the structure may be related to crustal compression producing buckling and thrust faulting; (3) it may be related to vertical forces which have arched up the crust and produced tension fractures out of which lava has poured. It is concluded that the Swell can be explained by arching of the crust above the zone of divergence between two subcrustal thermal convection cells. The deep terraces are presumably drowned shelves related to isostatic subsidence of the volcanoes. Because of crustal ridigity, the crust has been depressed beyond the limits of the superposed load to form the Hawaiian Deep. The Hawaiian Arch may possibly be related to an elastic bulge or to the outward displacement of viscous rock.

DISTINCTION BETWEEN THE DIFFERENT MEMBERS OF THE POTASH FELDSPAR GROUP USING ONLY A MICROSCOPE

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As the different members of the potash feldspar group have the same values of refractive indices and birefringence, overlapping values of the optic angles, and finally an often only apparent triclinic orientation determined with a microscope, the following data should be used for their distinction: (1) the presence or absence of microscopically visible lamellar twinning; (2) the optic angle; (3) the extinction angles or co-ordinates of crystallographic elements; (4) the interfacial angles; (5) the habit; (6) the paragenesis indicating the conditions of crystallization.

The general properties and some limitations of their values as they may be determined with a microscope are listed for the various members. The terms perthite and potash feldspar are briefly discussed. Detailed determination and publication of data especially of anomalous members are recommended.

AIDS FOR SINGLE-CRYSTAL TECHNIQUES

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Two nomographs have been devised which permit rapid interpretation of rotation and Weissenberg photographs. One of them gives, from a rotation photograph, the direct lattice translation of the rotation axis. The other gives, from a zero-layer Weissenberg photograph, the reciprocal lattice translations. The use of the charts, when they are carefully constructed, entails no loss of accuracy.

Many crystals can have one of their lattice rows adjusted only approximately by optical means. A simple procedure has been worked out in which the corrections to be applied to the arcs of the goniometer head are obtained from a single film, on which a 10-degree oscillation with unfiltered

radiation and a rotation with filtered radiation are superimposed. Measurement of the position of the continuous streak, due to the oscillation, with respect to the rotations record leads to the desired corrections.

CRYOLITE TWINNING

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The cubic pseudosymmetry of a multiple cell leads to the prediction of many twin laws, most of which have been reported by Brögger. The submultiple cell used by Dorothy Wrinch has the same shape as the multiple cell and therefore leads to exactly the same twin laws, but it has a structural significance which the multiple cell does not possess. Her interpretation of twinning can be generalized in that the submultiple cell need not be pseudo-cubic, but can be pseudo-orthogonal. Its validity as a law of observation can be established only by further experimental evidence.

MASCALL MIOCENE FAUNA AND RELATED ASSEMBLAGES FROM OREGON

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Three assemblages of fossils in central Oregon including those from the Mascall type area, the Crooked River area, and the Gateway area contain some identical taxonomic units and are considered as part of the Mascall fauna. The Crooked River assemblage has provided much new material for study, and this is the first report of mammals from the Gateway assemblage of Jefferson County, Oregon. Much undescribed material stored in eastern and western museums has been reviewed and described.

Geologic structure and lithology, particularly in the type area, indicates that the Mascall was probably deposited in a shallow synclinal basin with much water-laid and some wind-blown units, none of which are over 600 feet in visible thickness. The probable environment of the Mascall fauna constituted a valley with adjacent uplands; there were small lakes or streams and flood plains, some swamp elements (especially in the region of the floral deposit), forests, and grasslands.

A new species of the marmot-like rodent *Arctomyoides* and a heteromyid resembling the Dipodominae have been added to the fauna. Additional materials referable to known carnivores in the Mascall have been recovered. Study has shown that *Parahippus avus* (Marsh) is synonymous with *P. brevidens* (Marsh); *Merychippus isonesus* (Cope) is synonymous with *M. seversus* (Cope).

The Mascall is believed to be between Hemingfordian and Barstovian or Middle and Upper Miocene in age, thus demonstrating the continuity of time and events through "chronologic boundaries". There is no evidence for vertical differentiation in the formation or distinction of separate mammal horizons in the fauna.

STUDIES OF PLEISTOCENE STRATIGRAPHY ALONG LAKE ERIE IN SOUTHWESTERN ONTARIO*

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The pre-Wisconsin stratigraphy of this area is still uncertain because the older deposits are known from well records rather than from exposures. Some exposed beds, previously assumed to be interglacial by early workers, are shown to be interstadial.

* Published by permission of the Chief Conservation Engineer, Ontario Department of Planning and Development.

Recent ground-water studies around Aylmer revealed the existence of a buried shore line of an interglacial lake, in the Lake Erie area, probably of Sangamon age.

The Wisconsin drift shows at least two distinct till horizons separated by interstadial beds, mainly of lacustrine deposits. The older, sandy and stony till, accompanied by boulders of Precambrian tillite and jasper conglomerate, is correlated with the Iowan and Tazewell substages. Direction of ice flow indicates the existence of a local ice center, in the area now occupied by Lake Erie, during a part of the Tazewell substage.

Widespread lacustrine deposits of the Tazewell-Cary interstadial indicate that a glacial lake older than Lake Maumee occupied at least a part of this area.

The upper, mostly clayey till, with the absence of the above-mentioned type of boulders, is correlated with the Cary and Mankato drift—the last one limited to the eastern part of the area.

Velocity of retreat of the Cary ice margin, from the Norwich moraine to the Tillsonburg moraine, as calculated by studies of varved clays, has been 1½–3 miles per 10 years.

INTERRELATION OF STRUCTURE AND PENNSYLVANIAN SEDIMENTATION IN CENTRAL ILLINOIS*

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Structural studies in Ts. 6 to 9 N., Rs. 4 E. to 4 W. show the fundamental pattern of late Paleozoic structure to consist of three north trending belts: an eastern St. James-Louden anticlinal axis, a central trough, and the western Illinois shelf area.

Stratigraphic variations in these belts include pinching out of a thick sequence of lower Pennsylvanian sandstones against the eastern flank of the anticlinal zone, thickening of middle Pennsylvanian sediments in the trough, and thinning or overlap of beds in the shelf area. Coal is of normal thickness in the trough and shelf provinces but is thin over the anticline. Coal "cuts-outs" may be erosional or may represent areas in which conditions of accumulation were unfavorable. In either situation, the underlying cause may be structural. An unconformity below the West Franklin limestone is noted and may be of widespread significance. The western limit of West Franklin limestone appears to be controlled by the presence of the St. James-Louden axis, whereas to the west, only massive sandstone is present at this approximate position.

The integration of structural and stratigraphic studies should be of aid in evaluation of coal reserves, interpretation of pre-Pennsylvanian structure, location of stratigraphic traps, and other obvious applications. A program based on such studies, applied to larger regions and using appropriate sedimentological methods, will obviate the necessity for speculation and over-generalized theory.

CENOZOIC MARINE CLIMATES

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Studies of Cenozoic marine faunas on a world-wide basis show that the marine climatic (temperature) changes previously indicated for the Pacific Coast of North America on the basis of composition of the invertebrate faunas are paralleled in other parts of the world. Lack of precise correlations for many faunas and lack of marine deposits of particular ages in critical areas preclude an evaluation of the local changes on the same level of refinement as the studies for the Pacific Coast; however at an Epoch level the changes are of a similar nature.

During the Paleocene and Eocene the marine tropics were much more widespread than at present,

* Published with permission of the Chief, Illinois Geological Survey.

extending toward both poles from their present positions. Puget Sound, part of Japan, and the Paris Basin were within the northern limits of the tropics. All of Africa, Australia, New Zealand, and probably all of southern South America similarly were within the southern boundary of the tropics. During later Cenozoic time there was a gradual restriction, possibly with some fluctuations in the Pliocene and certainly so in the Pleistocene, of the tropics to their present comparatively narrow equatorial belt. This trend is in general agreement with that shown on land by Cenozoic fossil plants. It appears probable that our present relatively narrow tropical belt is an abnormal situation and that the normal condition is for it to be widespread, similar to that existing in the Eocene.

MODE OF GROWTH IN SOME ECHINOIDS

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Examination of a growth series of Recent *Dendraster excentricus* shows that all the plates of the oral surface of the adult test (75 mm. or more) are present in the smallest (4.4 mm.) specimen examined, and that growth proceeds by differential enlargement of the various plates. In the early stages the plates on the oral surface are arranged in a markedly different manner from those in the adult, but by a diameter of 15 mm. they have assumed the adult proportions and relationships. The arrangement of the plates in the early stages is similar to that of Early Tertiary scutellids and suggests that the phylogeny of the species is recapitulated in the changes occurring in the plate arrangement. A less complete series of the Recent *Heliophora orbiculus* shows that similar changes occur during the ontogeny of this species.

Weathered specimens of the Pliocene *Anorthoscutum interlineatum* commonly show concentric growth lines in the plates. Examination of the changes in plate shape shown by growth lines indicates that this species has undergone ontogenetic changes in plate arrangement like those of *Dendraster* and *Heliophora*.

Growth lines in the Recent *Strongylocentrotus franciscanus*, and weathered fossil specimens of *Echinodiscus*, *Pericosmus*, *Antillaster*, *Macropneustes*, and *Mellitella*, show that they are widely distributed among the echinoids. It appears that a suitable technique may demonstrate their presence in many if not all echinoids.

DEVONIAN FAUNAS OF THE WESTERN BROOKS RANGE, ALASKA

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Devonian faunas were collected over a wide area in the western Brooks Range of northern Alaska during the summer of 1950. Most of them are believed to be of Chemung age or younger. Coralline and stromatoporoid assemblages, however, may be of late Middle or early Late Devonian age. The widespread Middle Devonian *Stringocephalus* fauna has not yet been found.

Tentative correlations emphasize relationships with faunas of western Canada and the Cordilleran region; some Asiatic faunal elements are also present.

FACIES IN CARBONIFEROUS ROCKS OF NORTHERN ALASKA

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Distribution of lithofacies and biofacies in Carboniferous rocks of northern Alaska furnishes new evidence concerning some fundamental problems of paleontologic stratigraphy. In Mississippian

rocks of the Brooks Range, Alaska, the main lithofacies are black shale, arenaceous limestone, shelly light-gray limestone (with fragments of crinoids and brachiopods, and other marine fossils); shaly dark-gray limestone of "culm"-type lithology; and granule to fine pebble conglomerate. Biofacies include normal benthonic brachiopod-coral-bryozoan assemblages, pelecypod-gastropod-ammonite assemblages, colonial coral biostromes, and littoral brachiopod-pelecypod-trilobite assemblages.

The following relationships are discussed: transgression of lithofacies boundaries by biofacies that represent approximate time horizons; restriction of biofacies to certain lithofacies, probably denoting environmental or depositional control; and distribution of lithofacies and biofacies in time and space that indicates the tectonic and paleogeographic development of the region during late Paleozoic time.

RESTUDY OF THE TYPE WASATCH

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The type area of the Wasatch group is here considered to include the Evanston area of southwestern Wyoming and the adjacent area of Utah as far southwest as Coalville, Henefer, and Morgan. The Evanston area of Veatch has been remapped, much of the adjacent area in Utah southwest to Coalville has been mapped for the first time, and the Coalville-Henefer-Morgan area has been remapped following the writer's earlier endeavors there. Not all stratigraphic and structural problems are yet solved, but it can be said that the Fowkes is of local distribution and closely tied to the overlying Knight, that a wide-spread and orogenically significant unconformity separates the Knight from the underlying Almy and other formations, that the Henefer conformably underlies beds considered Almy, and is therefore probably a lower member of the Almy, and that the Almy was derived from several local sources, one as far east as Evanston, whereas the Knight came generally from the Wasatch Mountains on the west and the Uintas on the south. A formation with much tuffaceous sands and silts in it, and in places a coarse andesitic boulder conglomerate at the base, overlies the Knight unconformably. Its age has not been accurately determined, but it was mistaken for Fowkes by Veatch. An episode of faulting, probably of Basin and Range category, followed the deposition of the youngest formation.

ORIGIN AND EVOLUTION OF HORNBLENDE-ANDESINE AMPHIBOLITES AND KINDRED FACIES*

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Nearly identical hornblendic amphibolites, in which andesine is commonly a major constituent, may evolve from: (1) skarnlike metasomatism of carbonate sediments and (2) reconstitution without appreciable chemical changes of tuffs and marls, gabbro masses, diorite sills, and basalt flows.

Commonly no obvious physico-chemical feature of these amphibolites offers an unequivocal clue to their origin or evolution. The amphibolites occur in most older Precambrian terranes and in many younger orogens where each of the above-stated parent rocks and processes of formation are either apparent or readily inferred.

Clues to the derivation of these amphibolites seem to exist, however, in their differential inheritance of accessory elements. Amphibolites derived from mafic igneous rocks, for example, are, like their parents, commonly higher in Co, Ni, Cr, Sc, and Cu and lower in Pb, Au, and Ba than amphibolites derived from carbonate sediments.

Quantitative analyses of these elements in 82 parent rocks and amphibolites of known origin are

* Publication authorized by the Director, U. S. Geological Survey.

discussed in conjunction with other features of the rocks. Apparently dynamothermal metamorphism of the gabbros does not remove the initial concentrations of Sc, Cr, Co, Ni, and Cu as rapidly as it obliterates other diagnostic properties. Conversely, amphibolites derived by replacement of marbles tend to maintain higher concentrations of Ba, Pb, and Au than many known ortho-amphibolites.

The incipient granitization of amphibolites does not always obliterate the critical accessory-element differences at stages in which, by less subtle physico-chemical standards, various amphibolites are indistinguishable.

The accessory-element values in these amphibolites, and in some of their component minerals, are also compared with examples of enigmatic amphibolites from the Canadian Shield, the Alps, and elsewhere.

SOME GEOLOGIC CHARACTERISTICS OF URANIUM-BEARING VEIN DEPOSITS

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The geologic characteristics of primary pitchblende-bearing vein deposits in 12 significant districts throughout the world have been compiled and appraised. Special consideration has been given to: (1) nature and age of the host rocks, (2) mineral associations in the deposits, (3) paragenesis of the vein minerals, (4) structural relationship of the veins, and (5) hydrothermal wall-rock alteration, where it has been observed.

Three major structural belts in the earth's crust contain uranium-bearing vein deposits. These are found in western Europe and Africa, the western margin of the Canadian Shield, and the Cordillera of North and South America. Deposits in each of these belts appear to have in common certain geologic characteristics and ages of mineralization.

The present survey indicates that: (1) the most favorable host rocks are felsic igneous intrusive rocks and siliceous metasediments, (2) the common associated metallic minerals are copper, cobalt, silver, and lead sulfides and sulfarsenides and iron oxides, (3) the common gangue minerals are various forms of silica, iron-bearing carbonates, fluorite, and barite, and (4) the paragenetic position of pitchblende in the veins is variable, probably owing to the fact that it is deposited from a colloidal solution and the deposition, therefore, was not closely controlled by temperature.

Pitchblende deposits are largely emplaced within tensional structures that are commonly minor fractures associated with large-scale structures.

SILICIFIED TRENTON TRILOBITES FROM NEW YORK

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Silicified trilobites, etched from limestones of Trenton age from Clinton County, New York, include one species each of the genera *Ceraurus*, *Calyptaulax*, *Flexicalymene*, *Isotelus*, *Leonaspis?*, and *Diacanthaspis*. This is the first reported occurrence of silicified trilobites in the New York Trenton. This faunule is compared with a similar one described by Whittington from the Trenton of Virginia. With certain exceptions, the same genera are represented by very closely similar, yet distinguishable forms. This situation raises several questions, among them the following: Lacking knowledge of the precise correlation of the geologic horizons involved, are these to be considered separate species, subspecies, or varieties? Could the same distinctions be made if the fossils were preserved in the usual manner rather than as silica replacements? Additional information relating to the moult stages in the ontogeny of *Ceraurus* is outlined. A large number of transitory pygidia belonging to a species of this genus indicates that several moults may occur within one meraspid degree, and that a considerable size range is exhibited by specimens belonging to one degree.

NEW UNIVERSAL MICROSCOPE GONIOMETER

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The instrument consists of a standard synchronous-nicol microscope supported on a triangular base plate so that its optical axis is horizontal with what was its "north-south" vibration direction inclined downward to the left (as viewed from the ocular) at 45°. The crystal is mounted on a standard x-ray camera goniometer head in the usual fashion. This head attaches to a vertical axis with the crystal extending downward from it. The vertical axis, which is supported from the base plate independently of the microscope, is provided with two translation movements—one vertical, the other horizontal and normal to the microscope axis. The vertical axis has a graduated circle with vernier and tangent screw.

The crystal may be immersed in a suitable oil; this is held in a multiple cell of any convenient thickness. This cell, which has thermocouple wires for temperature measurement, fits in a frame supported on a vertical arm extending up from the base plate. The cell frame support is provided with two rack-and-pinion translations—one vertical, the other horizontal and normal to the microscope axis. The regular converger from the microscope substage is mounted "above" the stage so that it can be thrown in or out of the optical path; it is centerable and has a translation movement parallel to the axis of the microscope.

There is a detachable lamp housing with collimator and Webaky slit, so that the instrument may function as a one-circle goniometer by using the Bertrand lens.

The instrument may be employed for optical orientation of an anhedron. Or conversely it may be used to locate the optical indicatrix of an anhedron whose orientation has been obtained by any x-ray method. It is superior to the Universal stage technique for these purposes, since it is more general; thus no cleavage is needed for orientation purposes, and a single crystal with a single mounting is used for determining both the indicatrix and the lattice. Preliminary tests indicate it is superior to the U-stage in accuracy also. The tremendous advantage gained by the use of synchronously rotating nicols should be obvious.

IRON ORE AT BOMI HILL, LIBERIA

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The ore and siliceous iron formation at Bomi Hill, Liberia, are similar in character and occurrence to the better-known deposits of Venezuela and Brazil. Iron formation forms a hanging wall, and granite gneiss a footwall of the massive, high-grade ore. Ore outcrops and float show induration and recrystallization to a fine-grained, "steely" hematite. Similar transformations by tropical meteoric waters in Venezuela are noted. Canga capping is confined to the hanging-wall side of the Bomi Hill ore. This, together with comparable occurrences in Venezuela, suggests that the iron in porous limonitic canga is derived from iron-rich, siliceous rocks rather than from high-grade iron ore.

GEOLOGY OF THE CARRIZO MOUNTAIN SCHIST, TEXAS*

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The name Carrizo Mountain schist has been applied to Precambrian metasedimentary and metaigneous rocks of the Van Horn area, Texas. The unit includes feldspathic metaquartzite and meta-

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arkose, mica schist, chlorite schist, phyllite, slate, limestone, metarhyolite (in part mylonitized), and amphibolite. Regional metamorphic grade increases from northwest to southeast. In the northwestern area a retrogressive metamorphism has followed the regional metamorphism.

To the southeast the Carrizo Mountain schist is composed mainly of thoroughly recrystallized quartzofeldspathic rocks. Relict sedimentary structures are not evident. Associated almandine-bearing schists and amphibolites indicate a medium metamorpic grade. Crystalloblastic fabrics and equilibrium mineral assemblages characterize these rocks. To the northwest slate, phyllite, chlorite schist, and limestone occur with metaquartzite and meta-arkose. Cross-bedding is preserved in the quartzofeldspathic rocks. Cataclastic fabrics, fine grain size, retrogressive disequilibrium relations, smearing, comminution, microfolding, and microfaulting are characteristic here. The retrogressive metamorphism occurred during the period of dislocation in which the Carrizo Mountain schist was thrust northwestward over the Precambrian Allamoore limestone. Intrusive rhyolite and diorite (now metarhyolite and amphibolite) were affected only by this later cataclastic metamorphism.

OKINAWA AND THE RYUKYU ARC

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Okinawa includes areas representing two of the three concentric arcs that have been described as composing the Ryukyu chain. The northern two-thirds of the island, representing the central arc, is composed of highly deformed, metamorphosed, and intruded sediments of Paleozoic age. The southern one-third of the island, representing the outer arc, is composed of moderately deformed, poorly lithified marine sediments of Miocene age. Both areas have been terraced and locally coated with Pliocene and Pleistocene "reef-type" limestones. The difference in bedrock of the two areas is reflected in differences in topography, soils, natural resources, density of population, and culture.

The histories of the two parts of the island appear to have been independent of each other until late Miocene to early Pliocene time. Then the two portions were brought into their present relative positions. Since Pliocene time the two parts of the island have had similar histories. Okinawa has been eroded and has received sediments as an island mass in an unstable area. This is taken to indicate a late Miocene age for the present Ryukyu arc. This time of formation is much later than is commonly assumed. It is, however, consistent with the youthful characteristics of the arc, such as the fore and back deeps and the inner arc of active vulcanism.

POSSIBLE EUROPEAN CORRELATIVES OF WISCONSIN GLACIAL SUBSTAGES

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Radiocarbon dating has established beyond reasonable doubt the equivalence of the Two Creeks peat horizon in the Lake Michigan region to the widespread Alleröd horizon in Europe. It follows that the climatic fluctuation that resulted in the Alleröd-Two Creeks interval of relative warmth was common to both North America and Europe. The basis of the belief that Pleistocene climatic changes in general were contemporaneous over both continents is thereby strengthened.

Comparison of stratigraphic sequence within the Wisconsin glacial stage in America with those of the Newer Drift in Britain and the Weichsel drift in continental Europe, its presumed equivalents, reveals striking similarities. These constitute a reasonable basis for the belief that the same sequence of glacial substages characterizes both continents. It is likely, therefore, that the same series of climatic fluctuations affected both continents simultaneously during the Wisconsin glacial age.

PROBLEMS IN ENDOCEROID CLASSIFICATION

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Crucial features of endoceroid classification are found in the siphuncle wall and the endosiphuncle. Most genera fall into one of three large families: the Proterocameroceratidae, slender Middle and Upper Canadian endoseroids with short septal necks, the Upper Canadian Piloceratidae, in which holochoanitic necks appear, and the Endoceratidae, slender holochoanitic descendants of the Piloceratidae appearing first in the Chazyan.

Problems stem from (1) genera previously based upon gross features without knowledge of siphuncle wall or endocone pattern, (2) genera based upon isolated endosiphuncles only, (3) genera based upon early stages only. Evaluation of genera is still incomplete, but, even so, startling cases of synonomy have appeared. Redefinitions of familiar genera, as *Endoceras* and *Vaginoceras*, are formulated. *Cameroceras* and *Endoceras* are identical, with ensuing nomenclatorial complications.

Several new genera are described and illustrated, exhibiting new and bizarre types of endosiphuncles. Structures of the endosiphuncle are shown, and their morphological significance is discussed. As redefined, genera and families promise to have great stratigraphic and faunal significance.

GROUND-WATER BEHAVIOR IN THE HERSHEY VALLEY, PENNSYLVANIA

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The Hershey Valley, part of the Great Valley, is situated 9 miles east of Harrisburg, Pennsylvania. Beekmantown limestone (Ordovician), striking N.70°E. and steeply overturned to the southeast, underlies the valley.

The Annville Stone Company mines the high-calcium Annville limestone (top of the Beekmantown) 1½ miles northeast of the Hershey Chocolate Corporation plant. For many years 3500 gpm was the normal pumping discharge. Neither industry adversely affected the other nor any of the valley residents.

Plans of the Stone Co. to mine at lower levels prompted geologic studies by the Chocolate Corporation. One hundred wells and springs in the valley were systematically observed, 15 of the most critical being measured every 2 weeks. For each there was determined the water elevation; water temperature; pH value; ppm of dissolved solids; ppm of the Ca, Mg, PO_4, SiO_2, Al_2O_3, SO_4, and Fe ions; and yield in gpm of the springs. Details of ground-water movement were studied by using fluorescein. Piezometric maps of the valley were periodically made.

When the mine began pumping 6500 gpm from lower levels in May 1949 it drastically lowered the ground-water level over an area of 10 square miles, drying up all valley springs and many wells. About 100 sink holes of all sizes developed in the area, endangering life and property. The piezometric map of November 1949 showed a huge cone of depression with the apex at the mine.

Ground-water levels were successfully restored over a large area when the Chocolate Corporation recharged water to the ground, beginning December 1949.

1950 AND 1951 ERUPTIONS OF MIHARA YAMA, O SHIMA VOLCANO, JAPAN

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Mihara Yama is the active part of O Shima Volcano on the island of O Shima, Tokyo To, Japan. The outer slopes of O Shima Volcano compose the greater part of the island. The crest of the outer

slopes is a somma which averages 600 meters in elevation, 3 kilometers in diameter, and encloses a caldera. Mihara Yama rises from the southern part of the caldera to an elevation of 755 meters. It has the form of a truncated cone and contains a nearly circular crater, 800 meters in diameter. Before the 1950 eruption the crater contained a pit crater 170 meters deep and 300 meters in diameter.

Mihara Yama erupted on 16 July 1950 after 10 years of quiescence. Activity was continuous until 24 September 1950, when it ceased. It commenced again on 4 February and continued intermittently to July 1951.

The 1950 activity consisted of quiet emission of lava and explosive ejections of molten material. The more violent explosions threw ejecta more than 400 meters into the air, and three cinder cones were constructed successively. The pit crater and crater became filled with lava which overflowed into the caldera.

The 1951 activity was discontinuous, with periods of explosions and quiet emission of lava alternating with periods of inactivity. One large cinder cone and several small cinder and spatter cones resulted, but were largely destroyed by later explosions and subsidence of the crater floor. Flows, mostly of basaltic aa lava, covered large parts of the caldera floor.

ENGINEERING GEOLOGY IN BRAZIL

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Only recently has engineering geology, practically unknown before in Brazil, begun to be recognized in this country. Foundations for larger earth and concrete dams, tunnels, and underground powerhouses are demanding more geologic investigations. The recognition of potential and old landslides, their protection and drainage require considerable geologic exploration because heavy rainfall, deep rock decay, and steep slopes commonly result in many landslides.

However, the importance of engineering geology has been best demonstrated in the exploration of tunnels and of the sites for three large underground powerhouses of which two are now under construction and the third may be started soon. Exploration for tunnels present the most difficult geologic problems because of the obscurity of faults and bedrock by deep rock decay. More than 6 kilometers of large-diameter trans-mountain diversion and pressure tunnels have been completed in the last 2 years; extensive explorations for new tunnels are being made. Hydrothermally altered gneisses, fault zones, and hydrothermally altered syenites were the chief hazards to tunneling below the zone of weathering in the tunnels recently completed for the Paraiba-Pirai Diversion Project in the western portion of the State of Rio de Janeiro.

Complete decomposition of gneiss to a depth of 275 feet has been encountered by drill holes along a proposed tunnel in the State of São Paulo. In one area near Santos, totally decomposed rock was encountered to more than 100 feet below sea level.

Large deposits of gravel are rare because only vein quartz, cherts, and some quartzites have survived the agents of decomposition. No serious concrete deterioration with manufactured sand and aggregates on 50-year old structures of Brazil's largest utility has been recognized since freezing temperatures are unknown over most of the country.

HOEGBOMITE

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An investigation of the emery deposits of the Appalachian belt led to the discovery of a new hoegbomite locality in North Carolina, a reinvestigation of the Virginia hoegbomite, and an examination of a New York locality from which hoegbomite has not been previously described.

Of the eight known hoegbomite occurrences seven have been reported in emery, the emery being as a rule associated with basic rocks. Hoegbomite is a secondary mineral that formed by the replacement of spinel.

The hoegbomite of the New York emery deposits was formed later than the emery but earlier than the high-temperature quartz veins which represent the last stages of the intrusion that gave rise to the emery.

ROLE OF THE HYDROGEN BOND IN THE FORMATION OF SOME METASTABLE PHASES

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It has been well established that in the genesis of certain polymorphous mineral forms the pH of the crystallizing solution is a determining factor. However, the role of hydrogen has always been considered to be of a minor or secondary nature such as causing the formation of new groups or complexes that add to or remove from the solution inhibiting impurities. Recent chemical research and a close inspection of structural relationships indicate that the formation of metastable phases in the case of some polymorphic pairs, such as senarmontite-valentinite, can be explained by the hydrogen bond. The closer oxygen-oxygen distances that exist in the high-temperature form, valentinite, can be maintained during the growth of this form, well below its stable temperature range, through the formation of O—H—O bonds. Because of the small energies involved in the formation and rupture of the hydrogen bond, it is not believed necessary to achieve or retain measurable proportions of hydrogen in the crystals produced by this mechanism. The involvement of chemically bonded hydrogen in one phase and its absence in another restricts us from regarding the pair of phases in this instance as truly polymorphic; and consequently the generation of a phase containing hydrogen should not be considered a priori metastable.

MINERALOGY AND STRUCTURE OF THE LUZONITE-FAMATINITE SERIES

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New chemical analyses confirm that the formula of luzonite is Cu_3AsS_4 and that of famatinite is Cu_3SbS_4. They form an isomorphous series with the nearly pure end members occurring, respectively, at the type localities for the two minerals. Intermediate members of the series are also found at other localities. Crystals of luzonite from Mankayan, Luzon, Philippines, and of luzonite-famatinite from Goldfield, Nevada, were examined by goniometry and x-ray diffraction, and especially good x-ray results were obtained with fragments of famatinite from Sierra de Famatina, Argentina.

Luzonite-famatinite crystallizes in the tetragonal system, and luzonite is a polymorph of enargite. There are two cleavages, {100} and {101}. Twinning is on {111}, and the twin axis is normal to {110}.

The space group is $I\bar{4}2m$, and the cell is pseudo-cubic, with $a_0 = 5.27$ Å and $c_0 = 10.39$ Å for luzonite, and $a_0 = 5.38$ Å and $c_0 = 10.76$ Å for famatinite. Powder photographs show a sphalerite type of structure. The structure has been tentatively worked out, and can best be compared for illustration with that of stannite, with which it is isostructural. To do this, arsenic atoms take the place of iron atoms in stannite, and copper replaces the copper and tin atoms. This gives a body-centered tetragonal cell containing $Cu_8(AsSb)_2S_8$. Preliminary intensity calculations show this structure to be at least a very close approximation to the true structure.

SYENITES AND NEPHELINE SYENITES OF STETTIN, MARATHON COUNTY, WISCONSIN

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A southern extension of the complex crystalline rocks of the Precambrian Canadian Shield crops out in the Driftless Area of north-central Wisconsin, Stettin township, 8 miles west of Wausau, central Marathon County. A preliminary field survey was made of 6 square miles. A road-metal quarry in syenite (section 22, township Stettin) offered excellent, fresh-rock surfaces, in an area of otherwise scant and poor outcrops, where formerly only reconnaissance work had been done. Detailed study of the syenite quarry and adjacent ¾ square mile established (1) gray argillite, the original country rock; (2) "granite hybrid" with rounded included quartz grains; (3) nepheline syenite, bearing eucolite; (4) pink, fine-grained syenite apparently the main intrusive; (5) hornblende syenite in the pink syenite, possibly a darker phase of the syenite; (6) granite pegmatite containing zircon crystals. Nepheline was determined by treating slides with phosphoric acid and staining with methylene blue. A new occurrence of a mineral of the eudyalite-eucolite series was found, and determination was made by thin-section, fragment, and x-ray studies.

Nepheline syenites are often associated with limestones or carbonate rocks. There is no indication, up to the present time, of limestone in the Wausau area, although the argillite is rich in microscopic carbonate. These nepheline rocks and associated minerals resemble those of Magnet Cove, Arkansas; Haliburton-Bancroft, Ontario; Alno, Sweden; and Oslo, Norway.

Further field and laboratory work are needed to determine whether these rocks are igneous, metaigneous, or metasedimentary in origin.

ORIGINAL CRUST IN THE CANADIAN SHIELD AREA

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Archean rock series in the Canadian Precambrian Shield include sediments, but none of the coarse clastics characteristically derived from granite. This is taken as direct evidence that the original crust was basic, probably basaltic, and that granite was scarce, if not absent. The granitic rocks so abundant in the Shield developed and became exposed through repeated cycles of sedimentation, mountain building, and erosion.

NEW BASIC COPPER PHOSPHATE MINERAL FROM SANTA RITA, NEW MEXICO

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Crystallographic studies of small, emerald-green crystals from the Santa Rita pit, Chino Mines Division, Kennecott Copper Corporation, Santa Rita, New Mexico, lead to the description of a new mineral dimorphous with pseudomalachite, $Cu_5(PO_4)_2(OH)_4$.

X-ray studies by the Weissenberg method on the new mineral showed it to be orthorhombic and gave a space group Pnn—C_{2v}^{10} with cell dimensions $a_0 = 7.47$ Å, $b_0 = 8.31$ Å, $c_0 = 5.83$ Å and axial ratio a:b:c = 0.8989:1:0.7016. The unit cell contents are $Cu_{10}(PO_4)_4(OH)_8 = 2[Cu_5(PO_4)_2(OH)_4]$.

The optical data are: $\alpha = 1.698$, $\beta = 1.745$, $\gamma = 1.783$; $2V = 90 \pm$; optically (+); X = c.

Crystal forms present are b{010}, m{110}, n{011}. Cleavage is {110} perfect.

The calculated specific gravity is 5.22, and the measured specific gravity is 5.45.

OCCURRENCE OF DOLOMITES IN THE PENNSYLVANIAN OF ILLINOIS*

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Preliminary studies of limestone beds of the upper part of the Pennsylvanian system in Illinois indicate that, in addition to limestone, many of these rocks are dolomitic limestones, true dolomites, or iron-rich dolomites. Beds investigated were the Herrin, Bankston Fork, Cutler, West Franklin, Lonsdale, Shoal Creek, Millersville, and several unnamed underclay-type limestones. Samples were studied by means of differential thermal, X-ray diffraction, thin-section, and chemical analyses. Almost all samples were selected from unweathered diamond-drill cores from southern Illinois.

Results indicate that some of these "limestones" actually vary in composition from true dolomites through intermediate stages to true limestones. In the past many of these beds have been erroneously identified as limestones on the basis of gross lithology. More precise identification of the mineralogical constituents of these carbonate rocks may lead to better understanding of their petrogenesis and depositional environment.

SILICEOUS SEDIMENTS OF OUACHITA FACIES IN OKLAHOMA

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Field and petrographic study of the Bigfork chert formation, Arkansas Novaculite formation, and the siliceous shale members of the Stanley, Jackfork, and Atoka formations show that the Bigfork chert consists largely of siliceous limestone, chert, and black shale and may be divided into a lower part of gray to brown calcareous chert and siliceous limestone, and an upper part of alternating black paper shale and black noncalcareous chert. It is considered that the source of silica for the chert was extrusive Ordovician vulcanism; the change in lithology from the lower to the upper part results from increased argillaceous material and a gradual change from normal marine to euxinic conditions.

The Arkansas Novaculite may be divided into four members: from base to top these are (1) a light-colored, thin-bedded, argillaceous spiculite chert interbedded with hard, green chlorite argillite, (2) black to gray, pyritiferous, spore-bearing, argillaceous chert with abundant red-brown sapropelic matter, (3) red to green, silty, micaceous argillite, radiolarian siliceous shale, and black sapropelic chert, and (4) green, brown, and gray radiolarian chert and siliceous shale. It is considered that the silica of the Arkansas Novaculite formation resulted from submarine weathering (halmyrolysis) of volcanic ash.

The siliceous shales of the Stanley, Jackfork, and Atoka formations generally are thinly but irregularly laminated, carbonaceous, spinose, radiolarian- and spore-bearing siliceous shales in which the shreds of organic matter and streaks of clay have a wavy, crenulated appearance. At places the siliceous shales are associated with chert breccias. It is considered that the siliceous shales were formed in a lime-poor habitat near active wave base.

DEGLACIATION OF NORTH-CENTRAL BAFFIN ISLAND

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Barnes Ice Cap in the interior of Baffin Island appears to be the vestigial remains of a Wisconsin-age ice sheet radiating from central Baffin Island and covering all except possibly a few alpine summits. From the former ice sheet centered over the low hills of the interior, ribbonlike outlet glaciers

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once funnelled through mountains of the northeast coast developing a spectacular deep fiord system. Recession was principally by thinning registered by lateral moraines at all levels on fiord walls. Ice tongues receded to the inner fiords during a period as warm as and probably warmer than that of today—perhaps the climatic optimum some 5000 years ago—because silts containing a giant but modern fauna interfinger with a kame terrace and delta system 200 feet above present sea level. As ice receded farther to the interior the land emerged 50 to 100 feet, and a lower outwash-delta system accumulated. Finally interior ice withdrew west of the drainage divide of Baffin Island so glacial lakes were impounded. Outwash material then accumulated in these shifting lakes as a succession of underwater sand and gravel end moraines and lacustrine silts. This ponding reduced the load in glacial streams to the fiords so that earlier braided streams began to meander and to entrench former outwash. Each such outwash terrace relates to one of a multitude of lower and younger strand lines showing a continuing elevation of the land.

VARIATIONS IN DIFFERENTIAL THERMAL CURVES OF LOW-IRON DOLOMITES*

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Soluble salts, present to the extent of as much as 0.3 weight per cent, principally potassium, sodium, calcium, and magnesium chlorides, are a major cause of the variations in position and shape of the lower-temperature endothermic deflection in differential thermal-analysis curves of a number of low-iron sedimentary dolomites. Finely ground dolomites from which soluble salts have been leached give DTA curves like those of salt-free specimens. Conversely, the curves of essentially salt-free specimens to which dilute salt solution has been added duplicate those of naturally occurring salt-rich dolomites.

The particle size to which specimens are ground before differential thermal analysis becomes increasingly important in more coarsely crystalline rocks and results in the shifting of deflection temperatures without marked change in the shape of the deflections. Dilution of samples with noncarbonate material lowers the deflection temperatures because of reduced CO_2 partial pressure in the furnace atmosphere.

It does not appear to be possible to secure reliable estimates of the salinity of the environments of deposition of dolomites from the extent of distortion of DTA curves of dolomite.

AUROSTIBITE—A NEW MINERAL IN THE PYRITE GROUP**

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A new mineral identical with the intermetallic compound $AuSb_2$ has been found in gold ores from the Giant Yellowknife Mine, North-West Territories, and from the Chesterville Mine, Larder Lake Area, Ontario. In the former locality it occurs in dolomitic carbonate and quartz with gold, freibergite, stibnite, jamesonite, chalcostibite, bournonite, arsenopyrite, pyrite, chalcopyrite, and sphalerite; in the latter in quartz with gold, galena, tennantite, chalcopyrite, sphalerite, arsenopyrite, gersdorffite, and pyrite. In polished section the mineral is galenalike with a slight pinkish tinge; in hand specimen minute anhedral grains show a bornitelike tarnish. The standard etch reactions in the order of reactivity are: HNO_3, $FeCl_3$, HCl, KOH positive, $HgCl_2$, and KCN negative. The hardness is C—. The composition of the mineral was determined by comparing its x-ray powder pattern with that of the synthetic compound, and was checked by microchemical tests. The crystal

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structure is pyrite type; the unit cell containing Au_4Sb_8 has $a = 6.646 \pm 0.003$ kX (synthetic 6.644 $\pm$ 0.003 kX); the single Sb parameter is 0.386 $\pm$ 0.007. The calculated gravity is 9.91 compared with 9.98 measured on synthetic material.

PETROLOGY OF THE PALEOZOIC SHALES OF ILLINOIS*

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A series of Paleozoic shales ranging from the Ordovician through the Pennsylvanian from widely separated geographic localities in Illinois were investigated by x-ray diffraction, differential thermal, chemical, and microscopic methods, to determine their clay mineral composition and textural characteristics.

Illite is the dominant clay mineral in most of the shales investigated, a chloritic clay mineral is present in many of them in varying abundance, kaolinite is a component of many of them in varying abundance, and montmorillonite was found in only a few of them in minor quantities.

An analysis of the data shows that certain clay-mineral compositions are characteristic of certain parts of the Paleozoic section in Illinois. A discussion is presented of the relation of clay-mineral composition to the texture of shales and of the implication of the composition to the genesis of the shales.

URANIUM MINERALIZATION IN TODILTO LIMESTONE NEAR GRANTS, MCKINLEY COUNTY, NEW MEXICO

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Uranium ores have been found in Todilto limestone near Grants, New Mexico, about 75 miles west of Albuquerque. The rocks are a part of the southern rim of the San Juan Basin and dip gently northward. The Todilto is practically conformably underlain by Entrada sandstone. Summerville formation overlies it. The limestone in the area under discussion ranges from 3 to 20 feet in thickness. The upper part shows considerable recrystallization. It is in this portion that most of the mineralization is found. Here carnotite, tyuyamunite, uranophane, and some amorphous, ill-defined uranium-vanadium compounds partly replace the calcite. Fluorite has been found in two places replacing calcite. Pitchblende in minute blebs has been identified. The lower, thinly bedded limestone contains the uranium only along joints and fractures. Very minor amounts of uranium mineralization have been discovered in the basal few feet of the overlying Summerville. It may be stated tentatively that the uranium content is probably of syngenetic origin. Diagenesis caused recrystallization of the upper Todilto and some concentration of the ore. Circulating ground water caused much later solution and reprecipitation in the ores.

SPORE ANALYSES APPLIED TO A COAL CORRELATION PROBLEM IN SOUTHERN INDIANA

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The age of the Millersburg coal of Warrick County has been debated since Fuller and Ashley named it in 1902 and correlated it with Coal VII. Logan, in 1922, inferred that the Millersburg is a combination of Coals VI and VII. The late Doctor Malott thought that Coal VI might be absent

* Presented with the permission of the Chief of the Illinois State Geological Survey.

south of Monroe City in Knox County. In mining circles, however, the Millersburg coal is thought to be identical with Coal VI. The coal mined south of Elberfeld, by the Ingle Coal Company, and that stripped by the Sunlight Coal Company in the vicinity of Lynville, can be traced to Millersburg, Indiana, the type locality of the Millersburg coal. Spore analyses of the coal mined in these Warrick County localities show similar generic abundance patterns, substantiating this evidence. Thus the coal mined at Elberfeld and Lynville is the same bed, the Millersburg coal.

Samples of coal mined northeast of Winslow, Pike County, and southwest of Oakland City, Gibson County, which were thought to be Coal VI, were also examined. The resultant generic distribution patterns were compared to graphs derived for coals VI and VII. A striking similarity is apparent between the graphs representative of the coals from Gibson and Pike counties and the patterns representative of Coal VII. The distribution and abundance figures derived for the Millersburg coal, on the other hand, are dissimilar to the patterns representative of either Coal VI or Coal VII. The spore patterns for Coals VI and VII are quite diverse, so that any fused seam comprising both beds should show the same diversity. The upper part of the Millersburg, then, should resemble Coal VII in spore content, while the lower portion should be similar to Coal VI. However, this is not the case. The Millersburg coal revealed a uniform spore pattern, distinct from those representative of Coals VI and VII, leading to the conclusion that the Millersburg is not correlative with either Coal VI or Coal VII.

OPAQUE MATTER IN COAL

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The polished-surface technique is used to study the nature and occurrence of opaque matter in coal. The appearance of the opaque matter under reflected light was determined from a polished thin section, in which the opaque constituents were first established under transmitted light.

Two distinctly different forms of opaque matter are recognized—fusain lenses and opaque attritus. Based upon the presence or absence of a botanical structure, the opaque attritus is subdivided into two groups of opaque ingredients. For those devoid of structure the term micrinite is used. Micrinite occurs in three forms: finely divided granular, massive, and as groundmass. Opaque attritus with structure consists of fusinite, semifusinite, and sclerotinite (fungal tissue).

Evidence for the origin of the opaque attritus during the early stages of coal formation is given. A distinction is made between the opaque matter of "primary" origin, and the opacity of the high-ranking coals, which is due to increased coalification. It is shown that in anthracite the opaque matter of "primary" origin can be recognized under reflected light with the aid of etched, polished sections. No increase in the amount of "primary" opaque matter with increase in rank has been observed.

The percentage of opaque matter is determined with an integrating stage, using polished specimens of ground coal, mounted in lucite. The results are compared with the proximate analyses of the coal investigated. They show that a high percentage of opaque matter corresponds with a high percentage of fixed carbon and usually a high percentage of ash.

Photomicrographs illustrate the paper.

DOLOMITE IN THE ARBUCKLE LIMESTONE, ARBUCKLE MOUNTAINS, OKLAHOMA

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The Arbuckle limestone (Upper Cambrian and Lower Ordovician) ranges in thickness from 4000 to 6700 feet. It consists essentially of limestone and dolomite; the limestone originally was precipitated partly through the influence of algae but now shows extremely common clastic textures.

Dolomite occurs as (1) stratified layers ranging from laminae to sequences 1000 or more feet thick; (2) small, irregular bunches, knots, and stringers in limestone; (3) irregular bodies near faults, the size of the dolomite body locally embracing 1200 feet of beds and extending 3 miles from the controlling fault; and (4) detrital sand-sized fragments, in limestone, of dolomite rock, dolomitic limestone, and dolomite crystals.

Throughout the Arbuckle limestone, detrital dolomite is associated with limestone fragments derived from penecontemporaneous or slightly older beds, showing that the dolomite originated on the sea floor and thus indicating its very early introduction into the sediment. Stratified dolomite sequences of regional extent show sedimentational characters and likewise are of early origin, probably resulting from replacement of calcitic sediments by magnesium from sea water.

The fault-controlled dolomites were introduced much later, accompanying one or more of the strong orogenic pulses that deformed the Arbuckle Mountains in Pennsylvanian time. Part of this dolomite is ankeritic, containing a maximum of 8 per cent FeO.

The euhedral rhombic form of dolomite in limestone, its cross-cutting relations with limestone, and the occurrence of dolomite fossils and oöids all point to the general conclusion that dolomite here studied was formed by replacement of limestone.

PRACTICAL SIGNIFICANCE OF THE PETROGRAPHIC CHARACTERISTICS OF TWO KANSAS COAL BEDS

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The Mineral and Bevier coals of the southeastern Kansas coal field are remarkably uniform in chemical composition and are noteworthy because of their finely banded character. Translucent attritus is the principal petrographic constituent. The mineral content of the coals consists mainly of calcite and pyrite, but there are lesser amounts of aragonite, marcasite, sphalerite, quartz, apatite, and clay minerals.

The petrographic composition of the coals is related to several chemical and physical properties. Principal consideration is given to the friability of the coals and to their amenability to hydrogenation. A linear relation exists between the content of anthraxylon plus fusain and the fines which result from crushing coal. On the basis of the opaque attritus content, the coals will probably hydrogenate readily. The characterization of coal in terms of friability and opacity ratios is suggested. The distribution of mineral matter in Kansas coal is of such a character that the preparation of low ash coal concentrate is probably not economically feasible.

VARIATIONS IN GRANITIC ROCKS OF THE HUNTINGTON LAKE AREA OF THE SIERRA NEVADA, CALIFORNIA

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The rocks of the Huntington Lake area, 160 square miles of the western slope of the central Sierra Nevada, of California, are dominantly granitic. Two square miles of the area is underlain by metamorphic rocks, chiefly quartzites and marbles.

The granitic rocks vary from calcic diorite to alkali alaskite and form 12 plutons. Each pluton varies within itself, and a series of maps illustrate the following variables: rock type, abundance and relative proportions of ferromagnesian minerals, abundance of dark inclusions, grain size, and quality of primary flow structures. Gradational variations within plutons are of considerable magnitude in some cases; in two plutons, for example, rock type varies from quartz diorite through granodiorite to quartz monzonite. In another pluton, content of ferromagnesian minerals varies from 2 to 19 per cent. The "typical" granitic rock would be a hornblende-biotite-quartz monzonite.

Total dark minerals, soda lime feldspar, and the proportion of hornblende to biotite in general increase together; precise statements regarding their interrelation are not warranted.

The abundances of ferromagnesian minerals and of dark inclusions are closely parallel. The inclusions probably have a xenolithic origin.

ALLARD LAKE ILMENITE DEPOSITS

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The Allard Lake ilmenite deposits lie in the northeastern part of one of the large Precambrian anorthosite masses which are exposed at intervals along the north shore of the St. Lawrence River, in Quebec. The ore bodies consist of a series of narrow dikes, irregular lenses, or sill-like bodies which appear to be genetically related to the anorthosite rocks in which they occur. The ore is a black, coarse-grained aggregate of ilmenite, which holds numerous oriented microscopic lamellae of hematite. Grade of the material classed as ore averages 32 per cent TiO_2 and 36 per cent Fe.

The Lac Tio deposit, discovered by Kennco Explorations, Limited in 1946, is the most important ilmenite occurrence in the Allard Lake district and represents the largest body of titanium ore of its type now known in the world. Exploration of this deposit by diamond drilling and surface work has indicated 125,000,000 tons of ore in a tabular body 3600 feet long and 3400 feet wide, occupying an areal extent of 134 acres. Excellent possibilities exist for materially increasing this tonnage by lateral exploration of the ore body itself, and by the development of several satellite deposits.

An airborne magnetometer survey over approximately 1000 square miles of the anorthosite mass revealed no previously undiscovered deposits, but served as an excellent means of screening large areas of relatively inaccessible country. Strong negative anomalies were obtained from deposits of massive ilmenite, while in most cases positive anomalies were registered over areas of disseminated ilmenite.

Exploitation of the ore is proceeding rapidly, and recent production of iron and titanium dioxide-rich slag has been obtained at Sorel, Quebec.

FLATTOP RE-EXAMINED

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Flattop Mountain, Colorado, type local of Lee's Eocene peneplain was re-examined 1950 pursuant to research begun 1933 seeking adequate reasons for the origin of flat surfaces upon some Rocky Mountains especially the Laramies and Front Range which occur at various altitudes, various attitudes, and various directions inharmonious with the Tertiary peneplain theory.

Previous authors seemingly neglected to evaluate fundamental factors in Flattop's evolution, namely the effect of (1) the base-leveled regional surface cut upon resistant Basement Complex, (2) structural building, (3) weathered condition of that ancient important surface, (4) critical comparison with near-by Spanish Peaks devoid of peneplains.

One may tour afoot and by automobile partly with only negligible gaps this pristine base-leveled surface from the east foothills altitude 5129 with gradual ascent via Laramie-Front Range divide across Cache la Poudre Canyon, over Hague, Ypsilon, to Flattop 12,300 thence over Hallett, Taylor, Longs 14,255, and Alice 13,310 to Buchanan Pass 11,750. A rare relief of 9126.

Gullyless rubble-covered Flattop surface drapes gracefully over Continental Divide down each side beyond a mile nearly to upper limit 10,500 Pleistocene drift.

Flattop's northern slope surprisingly inclines 25 degrees. No Paleozoic or Mesozoic formations fragment or gravel was found upon Flattop; inference is their full thickness never was deposited upon Flattop.

Flattop monadnock is an integral relic of once lofty Archeozoic Mountains whose mellowed Everlasting Hills and senile parks controlled the location of Estes, Hellhole, Caribou, and other parks, major streams, glaciers, and the majestic inspiring Front Range scenery which slow persistent gnawing erosion is destroying.

ELEMENTS OF A PLAN FOR RESEARCH IN MOUNTAIN BUILDING

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No theory of orogeny is defendable until the complete stress cycle is known. Data from the Cayman Trough implies that compression is not a unique stress in forming geosynclines. This statement depends on the unproven equivalency of oceanic troughs and classical geosynclines. However, it does serve to illustrate the need to consider all possible flexing mechanisms. There are three: crustal buckling by compression, crustal sagging by loss of support, and crustal thinning by tension.

The problem of mountain building is confusing because there is no applicable doctrine of uniformitarianism to serve as a measuring device. The elements of the plan for the solution consist of establishing theoretical recognition criteria as an extension of the uniformitarianism principle. These must be formulated as predictions of the geologic responses to each flexing mechanism. Sample phenomena which may be integrated as diagnostic standards are: the placement and character of volcanoes; loci, amounts, and types of faulting; seismicity and its relation to relief; the mathematical expression of curvature; the fill form, its materials, and primary structures; and the geophysical anomalies. The operation of the plan requires comparison of recognition criteria with the field observations. The objective is the recognition of each mechanism and therefore its stress. Addition of well-documented compression and uplift stresses completes the cycle. This knowledge will permit the isolation of the "orogenic engine" by analyses already familiar in the literature. An absolute determination of the cause of orogeny should help define the physical constants of the earth's interior.

COLLAPSE STRUCTURE

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Astonishing structures ascribed to collapse under the influence of gravity were observed in Persia during 1933. The strata affected are massive formations of limestone interspersed with occasional packets of shale. They are arranged in large open folds of Jura type distinguished occasionally by anomalous structures as much as 8 miles long and 3 miles across. They appear to have resulted from gentle sagging in which the movement took place so gradually that in spite of strong deformation the rock sheets, already well jointed, did not disrupt. Several examples are known in Persia, and a few have been described from France. Elsewhere such features do not seem to have been recognized. On the other hand several varieties of collapse structure due to gravity have been noted in less robust formations; slumping and valley bulges are often encountered.

A school of thought however exists which sees in collapse under gravity, given abundant time, a factor in the building of mountains displaying complicated Alpine structures.

PETROLOGY OF THE FRANKLIN-SYLVA PEGMATITE DISTRICT, NORTH CAROLINA

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The Franklin-Sylva pegmatite district, which includes parts of Clay, Macon, Jackson, Transylvania, and Haywood counties in North Carolina, is underlain in its western two-thirds chiefly by high-grade metamorphic rocks and in its eastern one-third mainly by the Whiteside batholith, which

varies in composition from quartz dioritic to granodioritic and by whose crystallization the mica-bearing pegmatites were derived. The metamorphic rocks, which were studied by Keith, were divided by him into two formations: the Carolina gneiss, which included mainly biotitic gneisses and schists, and the Roan gneiss, which he described as dominantly hornblende gneiss and schist. More detailed work has revealed a much wider variation in rock types. Rocks previously classed together under Carolina gneiss include: biotite gneiss, biotite-garnet gneiss, biotite-muscovite gneiss ± garnet, quartz-biotite gneiss ± garnet, feldspathic biotite gneiss, garnetiferous quartzite, kyanite gneiss ± garnet or staurolite, kyanite-sillimanite gneiss and schist, sillimanite-biotite gneiss ± garnet, a series of rocks containing variable amounts of garnet (rhodolite), anthophyllite, biotite, hypersthene, sillimanite, and quartz, a group of rocks containing corundum in various combinations with garnet, biotite, kyanite, hypersthene, hornblende, or chlorite, and locally minor marble. The Roan gneiss is now known to contain hornblende gneiss and schist ± garnet, amphibolite, garnet amphibolite, and actinolite schist. This complex of probable Precambrian age was intruded first by bodies of dunite, troctolite, and peridotite, which display various degrees of serpentinization and complex hydrothermal alteration. Later, possibly in Carboniferous time, the Whiteside batholith with its satellitic pegmatites and aplites was emplaced, and migmatites were developed locally in the schists and gneisses through intense, small-scale injection.

SEDIMENTATION AND STRATIGRAPHY OF THE TIMISKAMING SERIES, KIRKLAND LAKE, ONTARIO

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The Timiskaming series of sediments and volcanics of Archean age occupy an area of 100 square miles extending in an east-west band from Kirkland Lake to the Quebec boundary. They are divided into a north belt and a south belt by the "Larder Lake break," a major east-west thrust fault. Both the north and south belt sediments rest on an erosion surface of folded Keewatin volcanics and truncate older folded structures in the Keewatin basement.

The most complete section of Timiskaming rocks is in Teck township, where over 11,000 feet of graywacke, conglomerate, tuff, and trachyte are present. The section is divided into seven members.

Examination of the pre-Timiskaming rocks exposed in the area, and study of the nature of the Timiskaming sediments, the pebbles of the conglomerates, and the heavy accessories of the grits and graywackes, allows reconstruction of the provenance area. The distributive province supplying sediments to the Timiskaming trough was composed of basic volcanics and intrusives, a great variety of rhyolites, trachytes, and associated acid porphyries, minor amounts of chert, iron formation, jasper, and slaty graywacke. Metamorphic rocks and large areas of unroofed batholithic granite, granite gneiss and syenite are lacking. Abundant acid porphyry pebbles were supplied by porphyritic volcanics and the dikes, sills, and cone sheets which formed part of centers of Keewatin acid volcanism.

The Timiskaming sediments are clastic, first-cycle sediments derived by the rapid mechanical disintegration of a rugged, folded Keewatin volcanic terrane. In some areas of the north belt much material was supplied by centers of trachytic Timiskaming volcanism, and trachyte flows and water-laid tuffs make up an important part of the section. The Timiskaming sediments were laid down in a geosynclinal trough flanking the Keewatin highland area and are marginal deposits of a shallow sea.

NOTES ON THE GEOCHEMISTRY OF BERYLLIUM

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Extensive sampling of nonpegmatitic rocks by the U. S. Geological Survey has provided many new data that suggest modification of prevailing concepts of beryllium geochemistry.

Common silicates, particularly those characterized by tetrahedrally co-ordinated aluminum, contain as much as 0.0X per cent BeO. Substitution of $Be^{2+}Si^{4+}$ for $Al^{3+}Al^{3+}$ is probable. Idocrase is exceptional in that it can contain a maximum of nearly 4 per cent BeO. When shown on a triangular diagram with coordination-number co-ordinates, nonberylliam idocrase analyses are grouped near Machatschki's formula $(Ca_{19}(Al, Mg)_{13}Si_{18}(O, OH, F)_{76})$. Idocrase with more than 0.1 per cent BeO lies far outside the normal field, but if beryllium is not included in the calculation the plots are normal. Probably a third of the beryllium replaces silicon; the rest enters normally unoccupied tetrahedral positions. Berylliam idocrase is known only at localities where beryllium minerals such as helvite are found. Garnet is similar to idocrase in structure, but it contains less than a tenth as much beryllium.

Igneous rocks vary widely in beryllium content. New tentative averages are: 0.0025 per cent BeO in feldspathoidal rocks, 0.002 in granitic rocks, and 0.0007 in intermediate rocks. Feldspathoidal intrusive rocks in the United States, including the rare pegmatitic phases, do not contain beryllium minerals. Beryllium is apparently accommodated in the lattices of aegerite and nephelite.

About 15 per cent of the pyrometasomatic deposits in the United States contain tactites with more than 0.005 per cent BeO, but none approach in size and grade the Iron Mountain, New Mexico, deposit. The association of idocrase, usually fluorine-rich, with fluorite is indicative of beryllium.

GEOLOGICAL PROBLEMS IN HIGHWAY DESIGN AND CONSTRUCTION IN KANSAS

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A questionnaire sent to all State Highway Departments shows a significant increase in the use of full-time staff geologists since 1949; existing staffs have been enlarged, and new staffs have been formed. Geologists function primarily in material surveys, location studies, bridge design, and road design; to a lesser degree they assist in answering questions arising in construction, maintenance, right-of-way including legal aspects, and soil mechanics.

Needs for research stemming from geologists in all phases of highway work focus on clay minerals, shales, foundation stability, and ground water as being the most necessary.

The chief geologist of the State Highway Commission of Kansas directs the activities of the geology section. Requests for work or information from the other major departments—Materials, Maintenance, Construction, or Division Engineers—are made directly to the Chief Geologist or through the Engineer of Design.

Functions of the geology section are: (1) preparation of subsurface data needed for bridge design; this includes the direction and operation of drilling equipment; (2) engineering geological surveys of road locations and classification of materials for excavation; (3) study and report on ground water as needed to determine location and kind of underdrains required in a given geological setting; (4) from time to time condition surveys, material surveys, and other surveys requested, which originate in any one of the other departments.

SURFACE TENSION AS AN EFFECTIVE FACTOR IN GRADATION

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The effect of surface tension as an agent of gradation is apparent widely. The volume of material removed at any one time is small, but the aggregate is significant. The details of the erosive action of surface tension as well as the protective action are discussed. The type of material affected, the results and land forms developed, and the distribution of the action of surface tension as a gradational process are given.

Vertical gully heads, boxhead canyons, road ditches, and other channel ways may retreat and widen by caving or collapse due to the action of surface tension of water. Hoodoo rocks, pedestals, table rocks, and other land forms are sculptured by the action of surface tension as well as by wind and running water. Though runoff may fall free over a vertical face, surface tension will deduct part of the water and divert it down the vertical face. Water held to the vertical face may enter an absorbent zone below a resistant layer and form mud causing collapse and the development of a cave or an overhang. In homogeneous sandstone grains of sand may be removed if the volume of water exceeds the surface tension, allowing a drop of water to fall free.

Surface tension combined with absorption of water may coat or "paint" vertical gully and valley walls with fine silt leaving a more resistant cover which prevents sloughing and spalling.

SEDIMENTARY FACIES OF THE LAKE SUPERIOR IRON-BEARING FORMATIONS, AND THEIR RELATION TO VOLCANISM AND GEOSYNCLINAL DEVELOPMENT

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In a previous paper, the suggestion was made that the sedimentary iron-rich rocks of the Lake Superior region can be divided into four primary facies—sulfide, carbonate, silicate, and oxide—depending upon the dominant original iron mineral. The characteristics and associations of these types are further defined. The general character of stratigraphic units is shown by means of a tetrahedral diagram, on which the chemical precipitates (sulfide, carbonate, oxide) occupy the points on the base, and silicate, which in part at least is iron-enriched fine clastic material, occupies the apex.

The relationship between the iron-rich rocks and volcanism is considered to be structural, not chemical; both are believed related to the development of the Huronian geosyncline. The lower Huronian rocks are iron-poor quartzite and dolomite—typical "stable-shelf" deposits; much of the Upper Huronian consists of iron-poor graywacke and slate with associated volcanics—a typical "geosynclinal" assemblage. Deposition of iron-rich beds in the intervening time requires the presence of closed or restricted basins, in which iron concentration could be built up. This restriction is believed to have been effected by structurally developed off-shore swells or island arcs that became loci for volcanic activity. During the early stages of development (Middle Huronian), the basins were shallow, and much of the iron-formation deposited is of the oxide and carbonate facies; in later stages (lower part of the Upper Huronian), the basins were deeper, and the iron-formation deposited is chiefly of the carbonate and sulfide facies.

BEDROCK DEFORMATION OF LATE QUATERNARY AGE AT TIGER BUTTE, NORTHEASTERN MONTANA

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In northeastern Montana most of the rocks are relatively undisturbed, and pronounced bedrock deformation is very unusual. At Tiger Butte, however, the strata have been tilted at angles ranging from 30° to vertical. Upper Cretaceous Bearpaw shale and Pleistocene gravels crop out in the group of hills composing the "butte," which is situated near the south side of the Milk River flood plain in Valley County. The gravels are dated by a mammoth tooth. A fault dipping 45° locally superposes Bearpaw shale on the Pleistocene gravels. The structure is such as to preclude ice shove as the cause of the deformation.

DISCONFORMITY AT THE CONTACT OF THE FOX HILLS SANDSTONE AND HELL CREEK FORMATION IN NORTHEASTERN MONTANA

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Field investigations in 1950 have shown that the Hell Creek formation rests disconformably on the Fox Hills sandstone (Upper Cretaceous formations) in at least parts of northeastern Montana. This finding is at variance with previous work by others. The disconformity is indicated by a sharp contact between the formations; by channels as much as 10 feet deep in the surface of the Fox Hills; by local differences in thickness of the Fox Hills (from 70 to 123 feet); by a change at the contact from fine and very fine sand and sandstone of the Fox Hills to medium sand and sandstone of the basal Hell Creek; and by numerous lenses of conglomerate in the basal Hell Creek, including some in channels of the disconformity. There are rounded gray quartzite pebbles and cobbles in the conglomerate lenses. The disconformity has been traced over a linear distance of more than 100 miles, from Devil Creek in Garfield County northeastward to T. 31 N., R. 43 E., in Valley County.

The Colgate sandstone member of the Fox Hills sandstone in central and western Garfield County changes facies to the east and becomes unrecognizable as a stratigraphic unit.

EVOLUTION OF NANTUCKET SHORE LINES

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Nantucket's shore line evolved through a much more complex history than has heretofore been recognized. As a part of the Wisconsin terminal moraine Nantucket, and neighboring islands, originated by partial submergence as a result of deglaciation. Once larger, it has been reduced by wave attack coupled with growth of bars, spits, and marshes.

Coatue and Great Points, prominent northerly projections of the island, are far from simple spits built by longshore currents, as was generally supposed. The former is a partially consumed plain of beach ridges. The unusual cuspate south shore was demonstrably carved by tidal currents in Nantucket Harbor. Great Point is in part a tiny remnant of an almost entirely consumed morainiec island. Its present form and connection to Nantucket effectively disguise the early history. Airplane photos aid in deciphering detailed structure and origin of these forms.

Nantucket approximates the line, according to Flint, at which postglacial rise of sea level just equals postglacial upheaval of the crust. Most previous workers in the area follow Johnson in concluding that submergence has been the only significant vertical movement of land with respect to sea in the past few thousand years. Abundant evidence, largely from abandoned strand lines and salt marshes, indicates that a slight elevation followed by a nearly equal submergence occurred long after the post-Wisconsin "marine limit" was established.

Form and composition of glacial deposits are so distinctive that classifying the entire New England shore line as "submergence" is misleading. Nantucket has both moraine and outwash-plain shore lines, each as distinctive as deltas and volcanoes, particularly in their sequential forms.

STRUCTURE OF THE KISSEYNEW GNEISSES IN THE WELDON BAY-SHERRIDON REGION, MANITOBA**

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The Kisseynew strata in northern Manitoba consist of complexly folded Grenville type sedimentary gneisses that have been intruded by granitic rocks. The plunge of most of the folds in the

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** Published by permission of the Director General of Scientific Services, Department of Mines and Technical Surveys, Ottawa, Canada.

Weldon Bay-Sherridon region has been determined by the writer. Although the lithologic units have a northerly strike, the folds plunge east at a shallow angle. If the lithologic contacts are projected parallel with the direction of plunge to a vertical plane, the folds are recumbent and strongly overturned from the north. According to this interpretation, the Kisseynew strata occur in two superimposed structural blocks, separated by a possible fault zone that exhibits a shallow eastward dip. In this construction the Sherridon structure appears in the upper structural block as a syncline, overturned from the north, with a disharmonious flexure on the south limb. This interpretation is in accord with most of the previously published structural data. The structural analysis also suggests that the Kisseynew paragneisses have been folded independently of the Keewatin type Amisk volcanic rocks to the south so that the two major lithologic units are probably separated along a major fault zone—the Kisseynew lineament.

VOLCANIC ROCKS IN GEOSYNCLINES

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Paleozoic and early Mesozoic lavas and indigenous volcanic fragmental rocks are limited virtually to belts along the Atlantic and Pacific coasts. Associated with varied marine sediments in sequences through Lower Devonian in the East and Jurassic in the West, they are in deeply subsided belts, eugeosynclinal, having orogenic welts at times and places: The eugeosynclinal belts had geography like modern island arcs; one followed the Atlantic and Gulf coasts, probably curving through Mexico into the Antilles; the other continued along the Pacific from the Aleutians to the Andes. Literature reports andesites and basalts more frequently than rhyolites, but each is prevalent locally. There is not an obvious orderly compositional change in local sequences. Later plutonic rocks are emplaced in the same belts that had had volcanics, but late Mesozoic plutons in the West extended considerably into the continental interior. Late Paleozoic sequences on the Atlantic Coast have some volcanic rocks in the epieugeosynclines of Maritime Canada; and the Triassic has widely distributed basaltic lavas in rift-bounded taphrogeosynclines. Most of the extensive Tertiary volcanic rocks are not in deeply subsided areas, hence not geosynclinal.

TECTONIC HISTORY OF THE LIMA REGION, SOUTHWESTERN MONTANA AND ADJACENT IDAHO

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The Lima region covers the Tendoy, Blacktail, and Snowcrest ranges, portions of the Beaverhead and Ruby ranges, and the intermontane basins. It is located in a critical tectonical position between the craton of central Montana and the miogeosyncline of central Idaho.

Pre-Beltian diastrophism is indicated by regional metamorphism and was accompanied by intrusion of the Dillon batholith. Fluctuations of the geosynclinal margin during the Paleozoic are reflected by horizontal and vertical transitions between near-shelf and geosynclinal sediments. Latest Jurassic and Cretaceous terrestrial clastics reflect near-by pulsations related to the Nevadan orogeny farther west.

The Laramide orogeny began with northeast folding, probably in Paleocene time, creating the giant Blacktail-Snowcrest anticline and associated folds. This was followed in early Eocene time by folding along northwest lines, which were superposed on the early folds. A subsequent phase of intense thrusting took place in the western portion of the region, leaving the eastern shelf area unaffected. The low-angle Medicine Lodge thrust had a displacement of probably more than 10 miles and carried the geosynclinal facies close to the near-shelf facies. It was subsequently broken and

tilted by the high-angle Nicholia, Cabin, and Tendoy thrusts. Granitic intrusion followed this orogenic phase.

Block faulting along the present northwest-trending mountain fronts may locally have started as early as late Eocene and in part continued into Recent time. Late Cenozoic compression created gentle north-south folds in the Tertiary basin beds. Widespread volcanic extrusions accompanied these movements.

CRETACEOUS IN THE PHILIPPINES

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Rare large Foraminifera, collected by geologists of the Philippine Petroleum Survey in 1939 from small lenses of marble in a metamorphic complex of central Cebu, were identified by the Survey paleontologists as *Orbitolina* (?), the complex tentatively dated as Cretaceous. More recent geologic mapping by the Philippine Bureau of Mines has greatly extended the known distribution of the metamorphic complex; additional foraminiferal samples have been sent to the Museum of Paleontology at the University of California in Berkeley. Preliminary studies verify the earlier more tentative identification and substantiate correlation of the containing strata as the first definite Cretaceous on record from the Philippines. Direct marine Cretaceous connections between southern Japan and the East Indies by way of the Philippines are indicated.

GIANT PLAYA-CRACK POLYGONS IN NEW MEXICO COMPARED WITH ARCTIC TUNDRA-CRACK POLYGONS

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Systems of giant crack polygons caused by desiccation in temperate to warm climates are apt to be strikingly similar in pattern to those caused by contraction of perennially frozen ground. Conceivably, therefore, giant crack systems might lead to misinterpretation if used indiscriminately as criteria of former periglacial climatic conditions. The possibility of confusing the two kinds of crack polygon systems is illustrated by aerial photographs (1) of Playa de los Pinos, at Conrad siding of the Southern Pacific Railroad, Hidalgo County, New Mexico, and (2) of a tract of Arctic tundra in northern Alaska.

CHEMICAL ANALYSES OF CONSTITUENTS OF CLARAIN*

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The banded ingredients of Illinois coal beds, as viewed megascopically, are vitrain, clarain, durain, and fusain. Vitrain and fusain from Illinois coal beds have received attention from various authors.

Studies of clarain were begun because it frequently constitutes 70 to 80 per cent of the coal beds and differs both megascopically and microscopically from vitrain and fusain. Megascopically clarain varies in luster from bright to dull and microscopically is a heterogeneous unit. It usually contains translucent humic degradation matter, spores, resins, cuticle, waxes, and mineral matter. A chemical analysis is therefore an average of this heterogeneous grouping.

In an effort to understand variations in chemical analyses and combustion characteristics, it was decided to explore the role played by the individual constituents of clarain. Employing several

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different methods, spores, resin rodlets, and cuticle were isolated, and microchemical analyses run. The carbon content of the resin rodlets exceeds 75 per cent, while that of the spores and cuticle is much lower, 58 to 63 per cent. Differences of this sort may provide information relative to the variations noted in chemical analyses and combustion characteristics.

AGE DETERMINATIONS BY CARBON 14

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Age determinations by natural radiocarbon have been made on wood, peat, shell, deep-sea cores, air and deep ocean water samples. These samples include Sequoia tree rings; wood covered by Mendenhall glacier outwash; charred wood under lava of the last great eruption of La Suffriere; charcoal from Signal Butte site, Nebraska; Bikini Lagoon carbonate sediments; prehistoric burned wood from widespread layer, St. George's Harbor, Bermuda; wood from Aleut midden, Shagak Bay, Alaska; and various North Atlantic cores. The geological significance of these results will be discussed.

THRUSTING AND CHAOS STRUCTURE IN THE SILURIAN HILLS, SAN BERNARDINO COUNTY, CALIFORNIA

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The Silurian Hills, 15 miles southeast of Death Valley, are composed principally of late Precambrian Pahrump rocks and the overlying Paleozoic (?) carbonate rocks of the Riggs thrust plate. The thrust surface is dome-shaped, probably because of post-thrust warping. The Riggs thrust is tentatively dated as younger than the folded Cenozoic (?) volcanic rocks which are confined to the thrust plate. Most of the granitic rock of the area is displaced by the Riggs thrust, but part was intruded along the thrust and then displaced by it. The thrust zone is a "chaos" similar to Noble's type Amargosa chaos. Unlike the Amargosa chaos, however, it is composed chiefly of rocks from the autochthon, thus eliminating the possibility of landslide origin. No post-Paleozoic sedimentary material is involved, thus eliminating other possible sedimentary origins.

Pahrump rocks in the Silurian Hills are coarse clastics, whereas 15 miles to the north they are fine-grained clastics and carbonates; thus a southerly sediment source is indicated. Silurian Hills Pahrump rocks, 11,000 feet thick, can be traced from unmetamorphosed sedimentary rocks into feldspathized, intruded, and metamorphosed rocks which previous workers called "Archean." Subdivision of the Pahrump rocks into 35 mappable members has made possible detailed mapping of the chaos. This mapping shows that component fragments in the chaos have been carried southwestward up to 2 miles from their original position in the autochthon, but have maintained their normal stratigraphic order. This southwestward movement of the thrust plate, a direction different from that found by workers in adjacent areas, is confirmed by drag structures.

WATER-SOLUBLE SALTS IN LIMESTONES AND DOLOMITES

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Leaches have been prepared from typical samples of most of the principal limestone and dolomite formations in Illinois by grinding the samples in distilled water and removing the resulting pulverized stone by filtration. Quantities of solids recovered from the leaches range between .04 and .30 per cent by weight of the original rock sample. Samples 300 feet apart from the same bed

showed reasonable similarity as to the amount and character of water-soluble salts. Chemical analyses and x-ray diffraction data reveal that the solids resulting from the evaporation of the leaches are composed principally of one or more of the following compounds: sodium chloride, calcium sulfate, calcium carbonate, and magnesium sulfate. Less commonly present are potassium chloride and magnesium chloride. Leaches from dolomites generally yield a greater percentage of solids than those from limestones. Probably most or all of the water-soluble salts occur as solids in the parent limestones or dolomites rather than as liquid inclusions.

ORIGIN OF THICK-BEDDED SALT DEPOSITS

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The following stages are suggested in the natural history of a major bedded salt deposit:

(1) Peneplanation of the continental platform so that it is a nearly flat land of very little elevation above the sea.

(2) Submergence of wide areas beneath the sea. Shallow ocean waters spread over a considerable part of the continent.

(3) Beginning or renewed downwarping of a basin marginal to this epicontinental sea.

(4) Sedimentation of both basin and epicontinental sea. Mainly clastic and organic (reef) deposits.

(5) Lowering of sea to approximately sill level. Period of evaporite deposition. Enrichment by sea water flowing across sill. Because of the shallowness of the water, and the distance from the open ocean in such areas as the Michigan Basin, the brine crossing the sill may have been abnormally strong due to a relatively high evaporation rate.

No doubt there was also some dilution taking place by streams entering the subsiding basin from the surrounding lands. The terranes drained by the streams entering these ancient basins were mainly shale and carbonate rock. Therefore the streams during times of normal flow brought in calcium and magnesium carbonate in solution. During flood stages fine sediment obtained from the outcropping shale and carbonate rock was carried in suspension into the filled basin. This situation has not been simulated in the chemical laboratory.

MOLLUSCAN FAUNA OF THE FLAGSTAFF FORMATION, CENTRAL UTAH

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The Flagstaff formation in central Utah contains a succession of nonmarine molluscan faunas of Paleocene and Eocene (?) age. The total assemblage of Mollusca consists of 5 species of pelecypods (genera *Elliptio*, *Sphaerium*, and *Pisidium*), 7 of land gastropods (genera *"Helix"*, *Pupoides*, *Albertanella*, *Lamellaxis?*, *Discus*, *Carychium*), and 20 of fresh-water gastropods (genera *Pleurolimnea*, *"Planorbis"*, *Physa*, *Ferrissia?*, *Viviparus*, *Lioplacodes*, *Amnicola*, *Hydrobia*, *Micropyrgus*, *Goniobasis*). Three new species are described, and three others, based on insufficient material, are discussed without formal description. The vertical distribution of the species provides a basis for dividing the Flagstaff formation into three zones. The comparative abundance of each species confirms the Paleocene age of the two lower zones and suggests an Eocene age for the upper zone. The two lower zones of the Flagstaff contain species represented in the Paleocene North Horn of Utah, Upper Saunders of Alberta, and Fort Union of western North America. The upper zone contains elements present in the Eocene of Utah and Wyoming. Study of the comparative abundance of the species composing the fauna yields evidence on the paleoecology of the three zones and the shifting shore line of the Flagstaff Lake. The history of the Flagstaff Lake is traced in broad outline,

from its restricted extent in Paleocene time, through its expansions and contractions, to its fina extinction in early Eocene (?) time. Relationships between the Flagstaff formation and the intertonguing North Horn and Colton are discussed insofar as they affect the changes in the molluscan faunas.

ON THE SUPERSTRUCTURE IN ANORTHITE

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Taylor and his coworkers (1934; 1951) have shown that in anorthite the true periodicity in the c direction is approximately twice that of albite. Additional observations here reported may be helpful in the final determination of the anorthite structure; considerable differences are observed with variation of heat treatment. Anorthites from several localities as well as synthetic anorthite show three types of reflections:

(a) (hkl) with l = even and (h+k) = even
(b) " " l = odd " " = odd
(c) " " (h+K+l) = odd
  (1) (h+k) = even, l = odd
  (2) " = odd, l = even

Type (a) spots correspond to those of the albite structure, are always sharp, and unaffected by heat treatment. Types (b) and (c) are affected by history and heat treatment. Types (b) and (c) can be diffuse, although (c) reflections are elongated in the direction normal to (0.10), when diffuse.

If all the spots are or have been made sharp (6 days at 1150°C for synthetic anorthite) the average ratio of the intensities of (a)/(c, 1)/(b), (c, 2) is approximately equal to 20/5/1. In 15 minutes at 1500°C the (c) spots virtually disappear so that the average intensity (a)/(c)/(b) is 20/0/1/. (The apparent disappearance of the (c) spots may be due to greatly increased diffusion, and must be checked photometrically.)

It is believed that these observations are best explained by assuming the (a) spots to be due to a fundamental plagioclase structure. The subsidiary spots (b) and (c) are a consequence of order-disorder relations with Al-Si ions controlling the (b) reflections, Ca ions the (c) reflection.

Additional data obtained from synthetic anorthites in which partial replacements were made of Al by Ga, of Si by Ge, and of both Al and Si by Ga and Ge confirm this hypothesis.

SOLUTION DEPRESSIONS IN DIORITE IN NORTH CAROLINA

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During 1950 more than 40 enclosed depressions, resembling sinks of limestone terranes, were observed by the writer in the igneous rocks of the Piedmont plateau of North Carolina. These depressions, averaging about 200 feet in diameter and about 3 feet in depth below the lowest possible overflow point, are restricted to upland areas of dioritic rocks.

That the agents of subaerial erosion are apparently incapable of forming these enclosed depressions indicates that ground water is the principal agent in forming them. The evidence indicates that soluble rocks underlie the depressions, that an appreciable amount of dissolved mineral matter is extracted from the dioritic rocks by ground water, and that surface subsidence is a consequence. More than three times as much mineral matter is extracted by circulating ground water from diorite as from granite, the most common rock of the Piedmont.

Solution subsidence is not confined to the enclosed depressions but is even more active in valley heads where the ground-water circulation and the consequent solution are greater. Studies in the

Piedmont of the occurrence and movement of ground water and an appraisal of data on the quantity and chemical quality of natural water reveal that ground water is a more significant agent in the erosion of igneous rocks than is generally believed.

STREAMLINING OF THE CAROLINA BAYS*

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Ground-water studies in the area of the Carolina bays have revealed a singularly consistent set of subsurface conditions when considered collectively. These conditions, apparently related to the origin of the bays, are (1) distinctly bedded clays in which at least one bed of limestone occurs, the limestone generally less than 25 feet thick and less than 150 feet beneath the surface; (2) a remarkably simple monoclinal structure, ideally suited for artesian conditions especially in the uppermost beds; (3) solution under artesian rather than water-table conditions in the near-surface bed of limestone, resulting in slow but regular removal of mineral constituents during long periods since deposition of the soluble beds.

This hypothesis supposes that solution in a near-surface artesian aquifer composed of limestone resulted in subsidence of overlying clay into this aquifer; thus a normal sink was formed. This condition was followed by stream-line ground-water flow around this impermeable clay obstruction. This caused increased circulation on the down-gradient side of the obstruction, leading to increased solution and subsidence in that area. The slow, continuous streamline flow of ground water around the impermeable clay enlarged the dissolved area into an ellipsoid, or, more generally, into an ovoid, the more pointed end of which is down gradient.

The hypothesis of stream-line origin apparently accounts for genetic features of the bays. Sand rims which characterize parts of some bays are considered as extraneous and as not requiring explanation under this hypothesis.

FRILLED ATRYPAS FROM THE DEVONIAN OF MANITOBA

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Atrypa characterized by strongly developed lateral and frontal wings or frills is common in the Devonian of Manitoba. Crowded layers of shells in hard limestone often show the delicate frills well preserved. These winged Atrypas named *A. reticularis* var. A by Kindle are now known to be either *A. arctica* Warren or *A. independensis* Webster. Warren illustrated *A. arctica* from the Ramparts limestone, but his specimens showed only the rough margins where the frill was broken away from the specimen. Several beautifully preserved specimens of this species from Manitoba with large delicate frills are now available for description and illustration, and they will be discussed by the writer.

GLACIAL LAKE SOURIS, NORTH DAKOTA

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Parts of north-central North Dakota and the adjoining Canadian province were covered by a Pleistocene (Wisconsin) lake known as Glacial Lake Souris. The part of the lake that lay in North Dakota was far smaller and shallower than previously reported.

* Publication authorized by the Director of the U. S. Geological Survey.

Delimitation of the areal extent of the lake, based on detailed mapping of lithologic differences between glacial lake deposits and surrounding glacial drift, mostly till, disclosed that the high-level stage of the lake did not exceed an altitude of 1540 feet at its southern end and about 1500 feet where it extended into Canada. At no place in North Dakota was the lake more than 100 feet deep, and in most places it was less than 30 feet deep. An earlier report indicated that its depth exceeded 600 feet. The part of the lake that was in North Dakota was about 90 miles long, and its maximum width was about 55 miles. Its areal extent was about 2400 square miles, or less than half the extent indicated in the preceding study.

Sand, silt, and minor amounts of gravel mantle the lake floor. Lacustrine clays, if present, underlie these deposits. Definable beach strands and other shore-line features are very indistinct. In a number of places wind action has produced dunes as much as 50 feet high from sandy parts of the lake deposits.

LINEAR CREVASSE FILLINGS, OUTWASH CHANNELS, AND OTHER SIMILARLY ORIENTED GLACIAL FEATURES IN NORTH-CENTRAL NORTH DAKOTA

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U. S. Geological Survey, Denver Federal Center, Denver, Colo.; Brown University, Providence, R. I.

In north-central North Dakota there are many remarkably well oriented linear glacial features of Wisconsin age. All trend southeast and exhibit conspicuous parallelism. Parallel ridges 3 to 30 feet high, a few hundred feet to 15 miles long, consist essentially of stratified drift and are regarded as crevasse fillings deposited in glacial ice. Glacial outwash channels, generally 10 to 30 feet deep, one-fourth to more than half a mile wide, and as much as 50 miles long, were formed at the margin of the retreating ice-front or in open fractures in the ice near the margin. Some other glacial features also exhibit a southeasterly trend.

Indirect evidence in this area and in near-by areas indicates that these features might reflect structural movement along well-oriented fractures in the underlying bedrock, the trend of the features being coincident with the lines of movement in the bedrock. Although this hypothesis is favored, additional studies based on subsurface data might explain the trend and origin of the features in another way.

PROBLEMS OF ALLUVIAL-TERRACE MAPPING FOR THE ENGINEERING GEOLOGIST

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Alluvial stream terraces are important to the engineering geologist. Cities and transportation lines are built upon them. The deposits of which they are the surface are a source of construction materials, and they contain large supplies of ground water. Terraces are commonly mapped by physiographic form but interpreted for engineering use in terms of underlying deposits. This hybridization of physiography and stratigraphy has led to inconsistency of mapping. Unpaired terrace remnants record merely lateral swings of a degrading channel and have little significance for regional mapping. Paired terraces record episodes of cut and fill, and the geologist must, in mapping, correlate remnants belonging to the same episode and having comparable characters. Correlations are hampered by overwash (alluvial fans, colluvium, talus) on the heel of the terrace; degradation of the surface near the scarp; false double scarps produced by differential erosion of terrace materials and

underlying bedrock; natural levees and channel scars on the terrace surface; slip-off slopes; and, in the Great Plains region, the merging of flanking pediments with terrace surfaces. Dissected high-level terraces are difficult to recognize and may be modified by a loess mantle or other secondary features. The engineering geologist must not rely on simple matching of level surfaces, but rather must reconstruct the physiographic history of the valley. He is concerned with materials underlying surfaces, not mere form, and for data to be of engineering value a map symbol should reflect similarities at depth. In areas where flanking pediments border terraces, subsurface exploration may be necessary for the adequate delineation of terrace boundaries.

RELATION OF FACTORS AFFECTING GROUND AND ROCK TEMPERATURE AT SHALLOW DEPTHS

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The depth-temperature curve for shallow depths results from the geothermal gradient and changes in temperature at the surface. The depth of penetration of cyclical diurnal and annual temperature changes is controlled by the thermal diffusivity and the period and range of temperature change at the surface.

The range of daily temperature changes attenuates rapidly with depth; in gravel the diurnal change at 10 centimeters is 42 per cent of the diurnal change at the surface. It is 8 per cent at 30 centimeters and 0.02 per cent at 100 centimeters; in limestone and quartz latite, however, rocks of twice the diffusivity of gravel, the corresponding changes are 55 per cent at 10 centimeters, 16 per cent at 30 centimeters, and 0.2 per cent at 100 centimeters.

The *annual* range in temperature on the other hand is perceptible to substantial depths. In quartz latite and limestone the range at 5 meters is 21 per cent of the annual range at the surface, it is 4 per cent at 10 meters, and 0.2 per cent at 20 meters. This is equivalent to a range of 11.55° F., 2.20° F., and 0.11° F., in the East Tintic district, Utah, in 1950. Temperature measurements made here throughout the year at the surface and in drill holes showed that, in the observed depth-temperature curves, the geothermal gradient was a factor additive to the calculated annual temperature variations. If, then, the surface temperature variation, the diffusivity of the rocks, the actual temperatures at various depths below the surface, and the time at which the temperatures were measured are all known, it is possible to calculate the geothermal gradient from relatively shallow holes. The difficulty of getting adequate data for precise calculations is substantial, however, and even under ideal conditions it is difficult to establish the geothermal gradient in holes less than 10 meters deep, if the rocks have thermal constants approximating those of limestone. Mean air temperatures and mean ground temperatures differ substantially from average ground temperature, and the reasons for this difference are discussed. In holes 15 to 20 meters deep it is possible to get fairly reliable indications of the geothermal gradient if readings are made through a period of several months. Anomalous geothermal gradients related to comparatively strong local heat sources such as oxidizing pyrite can be quickly ascertained in holes 30 meters deep; a local gradient not appreciably higher than the normal gradient might be difficult to determine at this depth unless a substantial amount of time was spent in obtaining background information for the region under investigation.

WINNIPEG FORMATION OF MANITOBA

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The Winnipeg formation outcrops alongs a narrow band on the shores and islands of Lake Winnipeg from Victoria Beach to the Narrows. In outcrop it is unconsolidated or partly consolidated

sandstone with shale stringers near the top; well sections in southwest Manitoba show shale predominant over sandstone.

The sandstone, composed of rounded quartz grains with minor amounts of only stablest heavy minerals and partially dolomitized calcite cement, is well sorted and medium-grained. The shale is pale green, highly siliceous.

Once considered equivalent to St. Peter, then Black River, and now Upper Ordovician, the Winnipeg constitutes basal Manitoba Ordovician on Precambrian. It has been suggested that part may be Upper Cambrian.

Fossils are rare except for algae, crinoid columnals, and bryozoans. The fauna is composed of 33 species. Many of them also occur in the overlying Upper Ordovician Red River and Stony Mountain formations.

Streptelasma is large and similar to Red River species, apparently forerunning them. *Conularia* precedes Red River *Metaconularia*. Graptolites are rare. Three Bryozoa species range to Stony Mountain. *Strophomena, Dalmanella, Platystrophia, Sowerbyella,* and *Lepidocyclus* resemble Red River-Stony Mountain species. Large Red River cephalopods *Endoceras, spyroceras,* and *Westonoceras* are rare. Also present are *Salpingostoma, Hormotoma, Modiolodon,* and *Ceraurinus.*

The close similarity of the Winnipeg and Red River-Stony Mountain faunas indicates one faunal unit for the Manitoba Ordovician. Thus it appears more likely that the Winnipeg is Upper rather than Middle Ordovician as previously suggested.

MICROFAUNA OF THE POTTSVILLE SERIES IN OHIO

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Three marine limestones in the upper part of the Pottsville—the Poverty Run, Lower and Upper Mercer—together with their associated shales and iron ores contain abundant microscopic fossils. These include wood particles and plant spores, Foraminifera, sponge spicules, crinoid plates, echinoid spines, Bryozoa, conodonts, ostracodes, and objects whose affinities are uncertain.

The ostracode faunas bear a striking resemblance to those of Illinois and the mid-continent. The Bairdiidae are the family most widely represented in number of genera and species. The genus *Bairdia* is conspicuous, as is the genus *Healdia* of the family Healdiidae. In number of individuals the species *Bythocypris pediformis* Knight exceeds all others and is present at nearly every collecting locality. Only one new ostracode species was found. This has been named *Sansabella stewarti.* Immature moults of this form bear a strong resemblance to *Beyrichiopsis modesta* Ulrich and Bassler, from the lower Mississippian of Tennessee, and suggest the possible derivation of the genus *Sansabella* from the genus *Beyrichiopsis.*

STUDY OF THE SEYLER THEORY OF COAL REFLECTANCE

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Investigations of the optical properties of the petrographic constituents of coal are reviewed, and a summary is given of the Seyler theory that the components of coal derived from woody tissue, such as anthraxylon and fusain, have reflectances that can be arranged in a discontinuous series. A description is given of the apparatus used to test this theory. The application of accepted reflectance theories to results obtained with this equipment on standard minerals is described, and the accuracy and duplicability of determinations on these minerals and on coal are calculated.

Graphical results are given of two procedures for testing the Seyler theory. The results are discussed, and a general appraisal of the theory is presented. It is concluded that Seyler's theory is

not substantiated by this study, but that his descriptions of reflectance variations in the constituents of coal may be of considerable value in petrographic analysis.

PROBLEM OF THE CARBONATE APATITES. IV—STRUCTURAL SUBSTITUTIONS INVOLVING CO_3 AND OH

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That the formula for francolite cannot be written correctly as $3Ca_3(PO_4)_2 \cdot CaCO_3$ is conclusively demonstrated by the fact that the atomic ratios Ca:P:C are not constant and do not closely approximate 10:6:1. Although certain authors have presumed that francolite consists of two phases, namely fluorapatite and $CaCO_3$, this presumption is inconsistent with most of the experimental data.

Optical and x-ray diffraction data completely fail to indicate the presence of a second $CaCO_3$ phase. If it is assumed that the $CaCO_3$ particles are so small as to produce no diffraction lines, one would expect the francolite lines to be broad and diffuse because the dimensions of the $CaCO_3$ particles could not be less than one-tenth the dimensions of the francolite particles. The diffraction lines of francolite are quite as sharp and narrow as those of apatite, however.

Although the diffraction patterns of apatite and francolite are similar, important differences exist. The optical properties are different also. Thus the basic structure of francolite must be similar to that of apatite, but certain statistical substitutions are necessary. Crystal chemical calculations indicate the following isomorphic substitutions: (i) C for P, i.e. $3PO_4 \rightarrow 4CO_3$, (ii) $(OH)_4$ for PO_4, and probably (iii) H_2O for Ca. This hypothesis is consistent with the average composition for five recent analyses of francolite, a fact which can hardly be fortuitous.

These concepts have important implications concerning the crystal chemistry of teeth and bones, because of the necessity for explaining the carbonate content of these substances in view of their apatite like diffraction patterns.

STRUCTURE AND COPPER MINERALIZATION AT THE ELIZABETH MINE, VERMONT

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Discovered in 1793 and worked at several periods since then, the Elizabeth mine has produced about 55 million pounds of copper of which some 45 million pounds represents production since reopening in 1943. The copper occurs as chalcopyrite associated with massive pyrrhotite. The sulphides form plunging podlike lenses, one of which has been mined continuously throughout a plunge length of over 5000 feet to a present depth of 975 feet lower than the outcrop. The lenses are replacement bodies in tightly folded sediments which are now metamorphosed to biotite schists. The ore bodies lie in the crease of an overturned syncline. In a broad way they are localized by plunging folds, and in greater detail by strongly deformed zones adjoining strike faults.

REPLACEMENT OF THE MIDDLE KITTANNING COAL BY INTERFINGERING CLASTICS IN SOUTHEASTERN OHIO*

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Mapping of the Middle Kittanning coal (Allegheny) in southeastern Ohio has permitted a limited study of a region in which the coal is largely absent and its stratigraphic position is occupied, in

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decreasing order of abundance, by shale, clay, flint clay, sandstone, and unfossiliferous limestone. The area in which the coal is missing comprises 37 square miles in Perry, Hocking, and Athens counties. It is divided into two irregularly shaped parts by a narrow, almost continuous belt of coal. Into these parts, linear, channel-shaped tongues of sandstone, disconformably replacing the coal, extend from several directions.

In this general vicinity, the Middle Kittanning coal is commonly between 7 and 14 feet thick, thicker than anywhere else in Ohio. The coal does not thin appreciably as the contact between it and shale and clay is approached; the change takes place through interfingering in distances of 6 to 100 feet.

Stratigraphic relations between the coal and the sediments replacing it, the general shape of the area in which the coal is missing, and the fact that this is a region of very thick Middle Kittanning lead to the conclusion that the coal is missing largely through nondeposition rather than post-Middle Kittanning Pennsylvanian erosion. Apparently, this area represents a portion of the coal swamp in which, except locally, the water was too deep to allow growth of vegetation. Normally, such an area would be gradually filled in by vegetation encroaching from the margins, but in this region peat-forming conditions for some reason never existed.

LOWER MISSISSIPPIAN NAUTILOID CEPHALOPODS OF MICHIGAN

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Nautiloids are not common fossils in the Mississippian strata of North America. However, both the Coldwater shale and the Marshall sandstone of the Lower Peninsula of Michigan have yielded a considerable variety of straight and coiled forms. Most of the specimens are fragmentary, but they seem to be referable to *Mooreoceras, Kionoceras, Cycloceras, Spyroceras, Poterioceras?, Tribuloceras, Vestinautilus,* and *Maccoyoceras.*

The cephalopods of the two formations, though close, show certain differences. The combined faunas are reminiscent of those known from the Chouteau formation of Missouri and the Tournaisian strata of Belgium. Furthermore, in each of these three occurrences, the nautiloids are associated with representatives of the goniatite genera *Imitoceras, Munsteroceras,* and *Protocanites*; and almost certainly all of the assemblages are of about the same age.

HURLBUTITE, $CaBe_2(PO_4)_2$, A NEW MINERAL

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A new calcium beryllium phosphate closely associated with triphyllite has been found on the dump at the Smith Mine, Chandler's Mill, Newport, New Hampshire. The original find of three crystals (summer of 1949) has recently been increased to 22.

Hurlbutite is orthorhombic-dipyramidal; crystals are colorless to greenish white, 4 mm. to 25 mm. along [110], stout prismatic [001] with observed forms {001}, {010}, {110}, {201}, and {311} doubtful. The faces often are delicately etched and show striations on {110}. Cleavage, not observed. Fracture conchoidal. Brittle. Hardness 6. Specific gravity 2.877 (meas.); 2.88 (calc.). Luster vitreous to greasy. Transparent to translucent. Optically biaxial negative (−) with nX = 1.595, nY = 1.601, nZ = 1.604; 2V = 70°; r > v, weak; X = b, Y = c. Chemical analysis gave: CaO 21.84, BeO 21.30, P_2O_5 56.19, Insol. 0.76, Total 100.09.

X-ray study by the Weissenberg method about all three axes was made on a single fragment of known orientation, drilled out from the original crystal found, following the location of the axes by the oscillating technique. Space group Pmmm. Unit cell dimensions a_o 8.29 Å, b_o 8.80, c_o 7.81

($a_o:b_o:c_o$ = 0.9420:1:0.8875). The strongest x-ray powder lines are 3.67 Å (10), 3.03 (9), 2.78 (9), 2.21 (9).

Hurlbutite occurs in a pegmatite of the complex acid type with lithium, beryllium, and phosphate phases. The mineral assemblage includes muscovite, albite, triphyllite, and massive light smoky quartz, with indications that hurlbutite is later than triphyllite but earlier than quartz. Perfect crystals are usually embedded in the smoky quartz. Secondary minerals include beryllonite, albite, brazilianite in parallel growth, twinned amblygonite crystals, colorless and purple apatite, siderite, and siderite psuedomorphs after hurlbutite.

UNIT CELL OF HYDROMAGNESITE

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X-ray study of crystals of hydromagnesite from Crestmore, California, by powder, rotation, and Weissenberg equi-inclination photographs, shows the following values for the crystallographic constants:

Monoclinic, pseudo-orthorhombic

$$a_o = 18.69\text{Å} \quad b_o = 9.02\text{Å} \quad c_o = 8.33\text{Å}$$
$$a:b:c = 2.0720:1:0.9235 \quad \beta = 90°$$

These values represent a doubling of the original a axis. Rotation and Weissenberg pictures were taken about [001] and [010]. The layer-line (equator, first and second layers) photographs show that the original a axis must be doubled, and also show systematic extinctions which apparently place the symmetry in class C_{2v}^{14} (orthorhombic). This apparent symmetry is produced by polysynthetic twinning on {100} which fails to appear in the layer-line pictures because of the orthorhombic aspect of the elementary lattice.

The powder photographs can be satisfactorily indexed using the new cell dimensions. Values for $\frac{1}{2}a_o$, b_o, c_o, and spacings and intensities of the powder photographs correspond closely with those determined by Fenoglio in 1936 on hydromagnesite from Pennsylvania and from Val d'Aosta.

OBSERVATIONS ON THE STRUCTURES OF SOME KAOLINITES AND DEHYDRATED HALLOYSITE

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The structures of several kaolinites and dehydrated halloysite, as indicated by x-ray powder diffraction technique and differential thermal analyses, have some significant variations. These variations are found within the unit structural layer and also in the manner in which the layers are stacked one upon the other. The term "degree of crystallinity" is used to compare the structural variations and is defined to include the disorder within the crystallographic unit layer and also the stacking variations of these unit layers.

The kaolinites and dehydrated halloysite were listed according to their degree of crystallinity first using criteria based on x-ray powder diffraction data and then using criteria based on differential thermal analyses. These two lists were compared and are in general agreement with the major exception of dehydrated halloysite.

Based on x-ray criteria, dehydrated halloysite has a poor "degree of crystallinity"; but, based on differential thermal criteria, it has a good "degree of crystallinity." This indicates that the unit layer has very little disorder but that these layers are stacked with complete randomness.

CHEMICAL COMPOSITION OF NORTH AMERICAN PRECAMBRIAN SLATES

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The average (unweighted) chemical composition of 33 Precambrian slates is: SiO_2—56.30, TiO_2—0.77, Al_2O_3—17.24, Fe_2O_3—3.83, FeO—5.09, MnO—0.10, MgO—2.54, CaO—1.00, Na_2O—1.23, K_2O—3.79, P_2O_5—0.14, combined water—3.31, moisture—0.38, CO_2—0.84, C—1.18, SO_3—0.28, FeS_2—1.98 (per cent).

The average comprises 9 analyses by the author and 24 analyses (21 published, 3 unpublished) of others. The geographic distribution of the samples is Ontario—4, Michigan and Wisconsin—18, and Minnesota—11. The stratigraphic distribution is Archean—5, Huronian—25, and Keweenawan—3.

Comparison of the Precambrian average with Paleozoic and Mesozoic-Cenozoic ones (Clarke) reveals that progressively younger averages contain successively less of Al_2O_3, FeO, total iron, K_2O, and C, and successively more of CaO, P_2O_5, moisture, CO_2, and SO_3.

Substitution of a Precambrian average weighted for sediment volume changed none of the trends. The validity of the Paleozoic average (51 samples) is attested by correspondence with the average of 36 American slates (Eckel), 27 of which are Paleozoic.

The Paleozoic shale and slate averages also indicate that chemical changes attending metamorphism of shale to slate are restricted to partial reduction of iron and loss of moisture and cannot account for the differences observed among the averages of the three ages.

The greater abundance of CaO, CO_2, P_2O_5, and SO_3 in the younger averages may be related to development of life, and the other consistent variations noted may be due to progressively coarser textures in the younger samples.

ORGANIC REEFS AND SUBMARINE DUNES OF OÖLITE SAND AROUND TONGUE OF THE OCEAN, BAHAMAS

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Progress is reported on studies of shallow marine geology and ecology made in 1950 and 1951 by Newell and student collaborators. A narrow reef and adjoining area extending some 116 miles along the coast of Andros Island was a special object of study, and scattered observations were made at a number of points on the banks east and west of Tongue of the Ocean.

Proximity to waters of Tongue of the Ocean and protection from the warm, hypersaline, and turbid bank waters characterize successful reef growth. The reefs are most luxuriant on bottoms between 3 and 5 fathoms deep, and they do not extend beyond 6 or 7 fathoms. Limitation to shallow waters possibly results from low winter temperatures. Since the Pleistocene maximum submergence reef growth has been dominantly horizontal as a result of gradual emergence of some 11 feet.

Deposits of the lime ooze, "coral" sand, and oölite sand are being formed. The origin of the oölite, which forms extensive systems of under-water "dunes", presents an unsolved problem. It is concentrated mainly around the edges of the banks where it is washed free of mud. Many of the parallel systems of "dunes" extend obliquely across the bank margin. Their form and orientation suggest that vigorous currents flow into Tongue of the Ocean. The "dunes" may result from tidal ebb with transfer of heavy bank waters into Tongue of the Ocean. Such currents, if they reached bathyal depths, might be effective in preventing accumulation of sediments.

GEOLOGIC SETTING OF THE MOUNTAIN PASS BASTNAESITE DEPOSITS, SAN BERNARDINO COUNTY, CALIFORNIA*

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Bastnaesite-bearing carbonate rocks at Mountain Pass, California, are related to potash-rich intrusive rocks, possibly of Mesozoic or Tertiary age, that cut Precambrian injection gneiss and granitic gneisses. The large intrusive masses, 300 or more feet wide, comprise one granite, two syenite, and four composite shonkinite-syenite bodies. One of the shonkinite-syenite bodies is more than a mile long. Several hundred relatively thin dikes of these potash-rich rocks range in composition and generally decreasing age from biotite shonkinite through syenite to granite. These rocks are cut by east-trending andesitic dikes and by faults, two of which form the west and north boundaries of known rare-earth mineralization.

Carbonate rocks and bastnaesite are most abundant in and near the southwest side of the largest shonkinite-syenite body. Although most bodies of carbonate rock are less than 6 feet wide, one large mass found in 1950 has a maximum width of 600 feet and is 2400 feet long. Calcite is the chief carbonate mineral in this body; the remainder of the rock is composed of barite, bastnaesite, and variable small quantities of quartz, crocidolite, biotite chlorite, apatite, iron oxides, fluorite, galena, and monazite. Additional minerals will probably be found by further study. The rare-earth oxide content in most of the carbonate rock is less than 13 per cent, but in some local concentrations of bastnaesie the content is as high as 40 per cent.

Rocks in the Mountain Pass area show certain petrogenetic similarities with rocks in Alnö Island, Sweden; Fen, Norway; and some localities in South Africa. Structure and composition suggest that the large carbonate body is genetically related to the differentiation of an alkaline magma.

PETROGRAPHIC ANALYSIS OF COLUMN SAMPLES BY COMBINED THIN-SECTION AND BROKEN-COAL METHOD WITH RESULTS ON A SAMPLE OF NO. 6 COAL FROM ST. CLAIR COUNTY, ILLINOIS

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Column samples completely representative of the full thickness of coal beds under investigation are collected for thin sectioning and microscopic analysis. The analysis gives quantitiative information relative to proportion of coal components present which permits type classification in accordance with Bureau of Mines method.

Supplementary information concerning physical characteristics is obtained by petrographic study of the coal reduced to small particle sizes. The technique involves controlled crushing, size classification with sieves, gravity classification with heavy liquids, and visual classification and quantitative estimation of coal and noncoal particles with aid of stereoscopic microscope. Ash and sulfur determinations are made in connection with the petrographic analysis.

The two petrographic methods of studying coal are discussed, with results of a combined analysis of a column sample of Illinois No. 6 coal collected for hydrogenation tests.

The thin-section analysis revealed a bright-type coal predominantly anthraxylon, 65 per cent, with minus 3 per cent opaque attritus. Petrographic composition of the coal exclusive of mineral matter was rather uniform. Pyrite in small crystals was found disseminated through much of the anthraxylon.

Results of broken-coal analysis and ash and sulfur determinations demonstrated that no big

* Publication authorized by the Director, U. S. Geological Survey

reduction of ash and sulfur could be expected by commercial coal cleaning. The relatively large amount of ash-forming mineral matter including the pyrite found in the basal 15 inches of the coal suggests that mining the coal above the blue band would yield a product which would not be materially further improved in commercial coal cleaning.

AGE OF MINERALIZATION: THERMOLUMINESCENCE AND RADIOACTIVITY OF FLUORITE

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The intensity of thermoluminescence of fluorite per unit radioactivity appears to be a function of the age of mineralization of the fluorite deposit. The intensity of thermoluminescence is proportional to the total radiation (alpha-particle bombardment) received by the crystal lattice from radioactive impurities in the fluorite. The total radiation received by a given sample is a function of the present radioactivity of the specimen and its age, or the length of time since its formation.

About 20 fresh (not exposed to sunlight) samples of fluorite were obtained from the principal fluorite-producing areas in the United States, and from other mineralized areas where fluorite was available and the approximate geologic age of the mineralization was known. The procedures and apparatus for measuring the thermoluminescence and the radioactivity of the fluorite samples will be discussed briefly.

The fluorite samples used in this study range from Precambrian to Tertiary. In most cases, the geologic evidence can only indicate an age as "post-this" and "pre-that," with perhaps a gap of a geologic period or more between the limits. With this new method involving the thermoluminescence and radioactivity of fluorite, the time of mineralization can generally be placed within a geologic period or a part thereof, according to the generally accepted absolute time scale of the National Research Council.

The possible sources of error, corrections involved, and the accuracy of this method are discussed briefly. This general method is probably applicable to all thermoluminescent minerals, including calcite, dolomite, feldspar, and quartz.

GEOLOGIC PROBLEMS IN DESIGN AND CONSTRUCTION OF HIGHWAYS IN VIRGINIA

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The Commonwealth of Virginia has within its boundaries portions of the following physiographic provinces—the Coastal Plain, the Piedmont, Blue Ridge, and the Valley and Ridge. Each of these provinces poses special problems in highway design and construction.

The high-water table in the Coastal Plain calls for grades to be raised above those normally used. Bedrock is far below the surface, and the variability of the unconsolidated sands and gravels in composition and thickness call for practically all bridges, including box culverts, to be placed on piling. The preponderance of sand and gravel virtually eliminates any aggregate problems.

The chief concern in the Piedmont Province is with unsuitable soils and a deficiency of acceptable aggregates. The disintegration of the igneous rocks and the metasediments in the southern piedmont has resulted in a mantle of residual soil which ranges up to 100 feet in depth. Bedrock is generally too soft to meet State specifications for all-purpose construction stone. Proper slope determinations are essential to prevent slides which occur within the soil mantle.

The Blue Ridge Province offers no particular problems in drainage and abounds in excellent aggregate. The main problem is to control slides and rock falls. Solid rock for bridge foundations is usually a few feet below surface.

Excellent aggregate abounds in the Valley and Ridge Province. The complexity of structure combined with numerous solution channels in limestone makes careful bridge explorations a must. Proper slopes, toe walls, sand drains, and grouting are necessary to minimize slides.

ORIGIN OF THE ASTRAGALUS IN THE REPTILIAN TARSUS

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The astragalar bone of a small species of *Captorhinus*, a captorhinomorph cotylosaur of Early Permian age, and of *Petrolacosaurus*, a primitive reptile of Late Pennsylvanian age, is demonstrably compound in origin. In the captorhinomorph the astragalus is clearly tripartite and formed by relatively simple fusion from the tibiale, proximal centrale, and intermedium of the labyrinthodont (*Trematops*) pattern. Thirty-five available astragali of *Captorhinus*, preserved nearly perfectly in Permian fissure deposits near Fort Sill, Oklahoma, all show in variable degree the tripartite structure internally as well as externally.

Heretofore, the astragalus of primitive reptiles has been thought to represent only the intermedium of the amphibian tarsus.

MAGNETIC SUSCEPTIBILITY OF CHROMITE FROM MONTANA AND ITS RELATION TO OTHER PHYSICAL AND CHEMICAL PROPERTIES

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Because qualitative tests have indicated considerable variation in the magnetic properties of chromite from the Stillwater Complex, Montana, a study was made of the magnetic susceptibility of cleaned chromite concentrates previously analyzed. The magnetic susceptibility, at a field strength of 6400 gauss, ranges from 5.16×10^6 to 121.94×10^6 Cgs units for 33 chromite samples from the Stillwater Complex, but for one sample from Red Lodge, Montana, it is 505×10^6 Cgs units. Complete analyses of 10 of the samples, and determination of Fe and Cr for the rest, had previously been made by R. E. Stevens and M. K. Carron of the U. S. Geological Survey. Preliminary microscopic study shows little evidence of nonhomogeneity; the magnetic properties are, therefore, considered as a property of the chromite itself. In general no correlation between magnetic susceptibility and weight per cent of total Fe is evident. Eight of the 10 samples analyzed for all major constituents show a linear relationship between magnetic susceptibility and the ratio

$$\frac{\text{Fe(mol)}}{\text{Fe(mol)} + \text{Mg(mol)}}$$

The variations of the physical properties and geologic occurrence of the magnetic and nonmagnetic chromite samples are compared with those of chromite from other deposits.

ORIGIN OF THE PORPHYRITIC PHASE OF THE STERLING GRANITE GNEISS IN CONNECTICUT-RHODE ISLAND

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The Sterling granite gneiss is a batholithic body, presumably late Paleozoic, in eastern Connecticut and western Rhode Island. The writer's investigations were in the Voluntown quadrangle,

about 20 miles northeast of New London, Conn. There the granite gneisses are in contact with the Precambrian (?) metasedimentary formation, the Putnam gneiss, hence contact phenomena can be studied.

The Sterling, although variable in composition and texture, may be divided into two main phases: alaskite and porphyritic granite gneiss. The latter is not a result of magmatic intrusion but of granitization of the Putnam gneiss.

In the Voluntown area, the Putnam is mainly quartz-biotite schists with some quartzites. These have been feldspathized, and the result is the porphyritic granite gneiss. The metasediments grade into the granite along and across the strike. The porphyritic texture is the result of microcline growth along schist cleavage planes. The foliation of the granite is an inherited structure. There is no evidence of forceful emplacement of magma. All contacts of the Sterling and Putnam are gradational, and structures of the granite are parallel to those of the country rock. Numerous oriented inclusions of schist are in the granite. These inclusions are unreplaced remnants of the host rock.

Petrographic studies support this thesis of a replacement origin for the porphyritic granite. Quartz and biotite of the schist have been replaced by microcline and plagioclase. The microcline phenocrysts often have schisty inclusions which are remnants of the schist.

FORAMINIFERA IN NORTH ATLANTIC DEEP SEA CORES

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Foraminifera have been studied from 39 long cores collected from the North Atlantic by the Swedish Deep Sea Expedition. These cores average approximately 10 meters in length. Distribution of modern Foraminifera have been studied from 60 undisturbed samples of surface sediment from the North Atlantic basin.

Modern planktonic Foraminifera in this region may be restricted to relatively low or high latitudes or may be generally distributed, and many distributions show a correlation with surface isotherms. Faunal variation with depth in the cores suggests changes in sea-surface temperatures; many or most of these may be correlated with Pleistocene climatic variations. A few cores contain Miocene Foraminifera in their lower sections, and a general transition from modern to Miocene forms is suggested. Faunas displaced from shallow water and occurring in deep-sea sand layers have been found off Brazil and Africa and are evidence of movement of large quantities of sediment from shoal into deep water in certain areas. These data have an important bearing on the mechanism and rate of sedimentation in the deep sea.

GEOLOGICAL PROJECTIONS UNDER VOLCANIC COVER, EAST TINTIC, UTAH

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The stratigraphy and structure of recently mapped sedimentary rock units exposed north of the younger volcanic rocks in the East Tintic district, Utah, indicate that the geology beneath this volcanic cover is complex. The sedimentary units studied include rocks of all Paleozoic systems from the Cambrian to the Carboniferous. The lavas and pyroclastic rocks that cover the Paleozoic sedimentary rocks on the east and south are early Tertiary and were extruded after the Paleozoic rocks were deformed.

These formations have been deformed into two overturned, asymmetrical synclines separated by a poorly defined anticline; these folds trend south toward the East Tintic district. Two west-dipping thrust faults, about a mile apart and genetically related to the folds, trend southward and pass under

the volcanic cover. Stratigraphic displacements on the faults reach 3000 feet. Several northeast-trending tear faults cut both the folds and the thrusts. Normal faults of small displacement occur on the west and north sides of the mapped area; a Basin and Range fault with hingelike movement bounds the west side of the mapped area.

Projection of the sedimentary beds and structures southward on strike under the volcanic cover should aid in a better understanding of the alteration patterns and buried structural features in parts of the East Tintic district, Utah.

"LEESPORT" AND "ANNVILLE" FORMATIONS OF PENNSYLVANIA*

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The indefinite status of the "Leesport" and "Annville" formations of Pennsylvania has prompted a study of their distribution, stratigraphic position, and composition.

The complex and doubtful nature of the type "Leesport" has resulted in inconsistent mapping of that formation and has necessitated new nomenclature. A few diagnostic fossils now help to determine the age of the formation.

The underlying "Annville" limestone, heretofore a commercial term for cement limestone in Lebanon and adjacent counties, was defined and given formational status. The unit shows much greater distribution than originally assumed, a fact of possible commercial significance.

Detailed measured sections of the "Annville" and "Leesport" indicate considerable horizontal facies change and help to demonstrate their lateral relationships with correlatives. Distribution studies based on the measured sections reveal information concerning ancient shore lines, distribution of isoliths relative to the structural belts, and several paleogeographic probabilities.

IRON-ORE DEPOSITS OF NEW QUEBEC AND LABRADOR

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The proved iron-ore deposits lie within a northwest-trending zone, 90 miles long and 12 miles wide, close to or astride the Quebec-Labrador boundary in the vicinity of latitude 54° 48′ N. and longitude 66° 50′ W.

The ores occur in iron formation near the top of some 2500 feet of Proterozoic sedimentary rocks resting on Archeozoic gneiss. These sedimentary rocks are in the "Labrador trough" which extends at least 500 miles northward from the central part of the Labrador peninsula. They consist in ascending order of slates, dolomite, chert breccia, quartzite, slate, iron formation and more slate, intercalated locally with volcanic flows. The assemblage is cut by diabase dikes, diorite, and gabbro. On the southwest tip, it is intruded and metamorphosed by a granite batholith. The iron-bearing portion is 30 miles across. In the northeast portion of the area there is an additional 30 miles of volcanics with minor sediments cut by serpentinite, diorite, and gabbro. These rocks are of uncertain age, but younger than the gneiss.

All the rocks have been folded and thrust faulted by a stress from the northeast, the resultant trend being generally northwest.

The ores consist of "limonite", hematite (some martite), and minor magnetite. Twelve per cent of the reserves is manganiferous. Some ore bodies occur along faults, others in the noses of folds, still others along straight limbs of folds. All probably were localized in permeable fracture zones resulting from regional deformation.

The ores were formed by meteoric waters acting on iron formation containing about 30 per cent

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iron, predominantly as oxides, less importantly as carbonate and silicates. These waters leached out silica and precipitated large quantities of iron oxide in the iron formation.

To the end of 1950, the reserve indicated by drilling was 417,707,000 long tons of high-grade, direct-shipping, open-pit ore. There are in addition very large, but unmeasured tonnages of lower-grade wash ore and ore that may ultimately be concentrated by gravity methods. Virtually untested by drilling or trenching are thousands of square miles of iron formation containing unknown tonnages of additional ore for the more remote future.

NEW MECHANICAL TWINNING IN CALCITE

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Cylinders of calcite were caused to deform by subjecting them to hydrostatic pressure plus additional compression parallel to the axes of the cylinders. The test specimens were right circular cylinders, half an inch in diameter, cut from single crystals of calcite; in one orientation the cylinder axes were perpendicular to a cleavage face $(10\bar{1}1)$, and in another orientation the axes were parallel to a crystallographic *a* axis. The resulting deformations were by twin gliding on the prism $\{10\bar{1}0\}$. Slipping on the twin plane for relatively large distances was observed and may be a parting mechanism of deformation with self-healing on the slip plane. The specimens were jacketed to prevent weakening by penetration of the pressure fluid into cracks. The shearing stress on the twin plane at the initiation of copious strain was not constant because of the irregularities of stress distribution in the cylinders, especially near the ends. A low hydrostatic pressure, less than 250 atmospheres, seems to be required before the twinning can be produced.

COMPOSITION AND SIGNIFICANCE OF FLUID INCLUSIONS IN MINERALS

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During the formation of many minerals small amounts of the fluid medium from which deposition occurred are trapped within the growing crystals as microscopic fluid inclusions. These inclusions thus represent a true sample of the original medium from which deposition has taken place, and any information, however meager, which can be obtained from them as to the chemical nature of these fluids would be of considerable value in such diverse problems as the origin of cherts, the identification and correlation of veins or epochs of deposition in faulted or complex mining areas, the origin of certain detrital sediments, and the origin and nature of the fluids which have deposited pegmatites, quartz veins, and the ores of the metals.

A technique has been developed for the extraction and limited wet chemical and spectrographic analysis of the fluid from fluid-filled inclusions in quartz. At present it appears adequate to yield significant data on the sulfate:chloride ratio, the K:Na ratio, and certain spectrographic determinations. The technique and its limitations are discussed, and results are given for quartz samples from a number of widely divergent types of occurrence, along with their significance in connection with the nature of the ore-forming fluid.

STUDIES OF MINERALS IN DUNITES AND IN OLIVINE-RICH INCLUSIONS IN BASALTIC ROCKS

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Dunites and olivine-rich inclusions in basaltic rocks, both of world-wide provenance and both characterized by the same four minerals—olivine, enstatite, diopside, and a spinel—provide an

unusual opportunity to compare the composition of the minerals and the distribution of the elements in them. These relationships contribute to an understanding of the genetic history of such rocks.

Materials were obtained from 14 widely distributed localities, and the various minerals were carefully separated for detailed mineralogical and chemical study. The analyses showed that the respective silicate minerals in olivine-rich inclusions and in dunites were strikingly similar in composition. This was particularly true of the olivine in which, for all the specimens studied, there was a range of only 1 per cent in the silica content and of only 2 per cent in the magnesia. Much greater differences were found in the composition of the spinel, particularly in that in olivine-rich inclusions, which differed greatly in iron, chromium, and, especially, in alumina content. The samples of spinel from dunites were very similar to each other and were much higher in chromium than were those from olivine-rich inclusions.

Their striking mineral identity suggests that the original source both of dunites and of olivine-rich inclusions is the same and that the inclusions are derived from the peridotite zone of the earth's crust, as has been commonly believed for dunites.

PROVENIENCE OF PYROCLASTIC MATERIALS

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Within recent years an intensified interest in the field occurrence of pyroclastic materials has developed in this and other countries. This is especially so of bentonite beds—a clay material derived from volcanic ash—which have stratigraphic as well as economic uses; and of welded tuff beds, many of which in the past were considered to be lava flows and are now receiving intensive study.

Ash materials that fall upon land are subject to erosion and removal from the geologic record, but locally large bodies like the San Juan tuff of Colorado, with an estimated volume of 700 cubic miles, are known. The volumes of ash that have been eroded and incorporated with clastic sediments must have been large.

Welded tuffs cover immense areas in the western United States, and locally attain great thicknesses. Numerous districts have been recognized in which volumes of hundreds of cubic miles are indicated.

Bentonite beds do not commonly attain such great thicknesses, but they cover very large areas not only in regions of recognized volcanism, as in the northern Great Plains region, but also in the Gulf Coastal region and in the eastern United States.

Welded tuffs in very large volumes have been recognized in New Zealand, Australia, Japan, Sumatra, Mexico, and Peru.

In the few areas where mapping has been detailed enough to give approximate volumes, pyroclastic materials are known to exist in volumes measurable only in hundreds of cubic miles. Thus pyroclastic materials clearly constitute a dominant portion of volcanic rocks of the rhyolitic and related types.

DETERMINATION OF SMALL QUANTITIES OF DOLOMITE BY DIFFERENTIAL THERMAL ANALYSIS

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In a furnace atmosphere of CO_2 the two endothermic loops of dolomite are separated and sharply defined. The first, between 700°C and 800°C, is formed during the decarbonation of the magnesium carbonate. The second, between 900°C and 1000°C, accompanies the decarbonation of calcium carbonate and coincides with the thermogram loop for calcite. The ratio of the areas enclosed by these

loops and the extended base line is directly proportional to the dolomite content of a carbonate rock, and the area of the first loop reflects the dolomite content of other rocks when only a small amount of dolomite is present. Calibration curves are obtained by plotting these areas or area ratios from thermograms of prepared mixtures against the known dolomite content. For mixtures containing less than 5 per cent dolomite, the first loop is recorded at a sensitivity about 30 times as great as the sensitivity used for the second loop. The change from high to low sensitivity is made at 850°C. This method, by which the dolomite content of a carbonate rock can be quantitatively determined when as little as 0.3 per cent dolomite is present, is most useful in following dolomitization far beyond the limits of microscopy or x-ray diffraction and in evaluating the products of experiments in the laboratory synthesis of dolomite.

THE SYSTEM $MgO—Al_2O_3—H_2O$

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Phase equilibria in the binary systems $MgO—H_2O$ and $MgO—Al_2O_3$ were investigated. New data in the former system indicate that the transformation $Mg(OH)_2 \rightleftharpoons MgO + H_2O$ takes place from 700° to 800°C varying within the range of water vapor pressures studied (2000–20,000 psi.). In the system $MgO—Al_2O_3$ spinel solid solutions were formed containing up to 85 mole per cent Al_2O_3. Exsolution of the solid solutions was accomplished under both dry and hydrothermal conditions. The extent of solid solution was found to decrease with decreasing temperature, the limit of solid solution being 65 mole per cent Al_2O_3 at 1500°C, and exsolution being almost complete at 800°C in the presence of water vapor.

Under hydrothermal conditions, spinel was formed at temperatures between 900° and 375°C. At temperatures lower than 375°C it is replaced by brucite + diaspore. Hydrotalcite ($6MgO \cdot Al_2O_3 \cdot CO_2 \cdot 12H_2O$), a mineral occurring naturally as a decomposition product of spinel, was synthesized below 310°C under varying H_2O and CO_2 pressures. A nitrate analogue of hydrotalcite was also synthesized at temperatures below 420°C under hydrothermal conditions. This compound was found to coexist with spinel between 420° and 375°C below which spinel no longer forms.

PHASE EQUILIBRIA IN THE SYSTEM $Al_2O_3—SiO_2—H_2O$

Rustum Roy and E. F. Osborn
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The equilibrium assemblages of phases in the system alumina-silica-water have been studied under hydrothermal conditions over the range of 100° to 950°C and 15 to 30,000 psi. Seven curves of univariant equilibrium are presented on a pressure-temperature diagram, representing the conditions at which one set of stable phase assemblages gives way to another. Two new phases are reported, one a pure aluminian end member of the montmorillonites and the other a micalike phase formed on the decomposition of kaolinite.

The data serve to establish the stability relationship of endellite ($Al_2O_3 \cdot 2SiO_2 \cdot 4H_2O$) to halloysite ($Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$). The decomposition temperature of endellite changes from just above 100°C at 15 psi. water pressure to nearly 200°C at approximately 10,000 psi. The equilibrium decomposition temperature of the kaolinite group of minerals was found to be 450°C and is very similar for the various members of the group. Pyrophyllite is a stable phase in equilibrium with a fluid in the system $Al_2O_3—SiO_2—H_2O$ from 420° to 575°C. At temperatures above 575°C mullite appears as a phase in all mixtures. It was not found possible to synthesize andalusite, sillimanite, or kyanite under any of the conditions used; however, these minerals were successfully decomposed to yield equilibrium phases. This latter decomposition was achieved in an apparatus for grinding at elevated temperatures (up to 500°C) and pressures (up to 10,000 psi.).

STRUCTURAL PATTERN IN THE OVERTHRUST ARC OF WESTERN WYOMING AND ADJACENT STATES*

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An arcuate zone, about 60 miles wide, of overthrusts and overturned folds rises from beneath the Snake River lava plain of southeastern Idaho, passes southeastward to west-central Wyoming, follows southward along both sides of the State line, and turns back southwestward to the Wasatch Mountains near Salt Lake City, Utah, —a distance of 250 miles along 120° of arc. The zone is indistinctly bounded on the west but well defined at its eastern perimeter between the Teton and Uinta Mountains.

Most of the subparallel mountain ranges of the arc are bounded by relatively flat major overthrusts on the east and later normal faults on the west. Within the mountains, the rocks are crumpled by lesser thrusts and overturns and torn by diagonal flaws. Well-known overthrusts of this arc, from west to east, are the Putnam, Bannock, Crawford, Absaroka, and Darby. Mapping by the writer in the middle third of the area and by others near by adds several other overthrusts and suggests restriction of some of those previously named. Many of these overthrusts maintain surprisingly uniform stratigraphic throws of 12,000 to 18,000 feet for many miles along the strike. Horizontal displacements are difficult to estimate, but stratigraphic throw and lateral extent suggest that the Absaroka is the largest overthrust within the arc.

The rocks involved are dominantly geosynclinal sediments of Cambrian to Cretaceous age; but Paleocene, Eocene, and later Tertiary rocks are also disturbed locally. Most major stratigraphic units double in thickness every 10 to 15 miles westward, and maximum thicknesses within the entire zone total well over 90,000 feet. Cretaceous rocks do not extend westward across the zone, however, and thicknesses in individual synclines total only 20,000 to 25,000 feet.

SYSTEM $FeO—Al_2O_3—SiO_2$

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Phase-equilibrium studies of this system, at and just below temperatures where a liquid phase is present, show one ternary compound, the iron analog of cordierite ($2FeO \cdot 2Al_2O_3 \cdot 5SiO_2$), which decomposes at 1210±10°C. to mullite, tridymite, and liquid. The fields of stability of corundum, mullite, hercynite, iron cordierite, cristobalite, tridymite, fayalite, and wüstite have been delineated. The following invariant points (the first two eutectics and the remainder reaction points) were located:

Fayalite + wüstite + hercynite + liquid 1148 ± 5°
Fayalite + iron cordierite + tridymite + liquid 1083 ± 5°
Fayalite + iron cordierite + hercynite + liquid 1088 ± 5°
Hercynite + iron cordierite + mullite + liquid 1205 ± 10°
Iron cordierite + mullite + tridymite + liquid 1210 ±10°
Corundum + mullite + hercynite + liquid 1380 ± 5°
Cristobalite + tridymite + mullite + liquid 1470 ± 10°

Iron cordierite crystallizes with some reluctance, and the metastable invariant points fayalite + tridymite + spinel + liquid at 1073 ± 5°, and mullite + hercynite + tridymite + liquid at 1205 ± 10° can be realized. No ferrosilite or almandine garnet could be crystallized from the melts at any temperature even when melts were seeded with these crystalline phases. Natural almandine from Botallack, England (91.3 per cent almandine), when heated begins to decompose at an ap-

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preciable rate as low as 900°C. and yields a mixture of hercynite, iron cordierite, and fayalite. The bearing of these results on petrology and slags is discussed.

MARGARITE-EPHESITE SERIES; THEORY VERSUS FACT*

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The formula of margarite, the best known of the brittle micas, $Ca \cdot Al_2 \cdot Al_2Si_2 \cdot O_{10}(OH)_2$, requires 14.09 per cent CaO. Yet not a single one of nearly 5 dozen analyses shows this much CaO.

The presence of several per cent of Na_2O in many margarites has long been known—the soda margarites. Substituting one sodium for one calcium in the margarite formula leaves a deficiency of one in the cation charges. Theory calls for the addition of one atom of a univalent element whose ionic radius is close to that of aluminum in order to balance the charges. Lithium is the only element which meets these requirements, and it goes into the only vacant position, in the octahedral group, of the margarite formula. The theoretical formula of the calcium-free sodium analogue of the margarite formula thus becomes $Na \cdot Al_2Li \cdot Al_2Si_2 \cdot O_{10}(OH)_2$, the mineral ephesite.

Now what are the facts? The calculated amount of Li_2O in the ephesite formula is 3.85 per cent. The two recorded analyses of ephesite from Postmasburg, South Africa, show only 0.9 and 1.5 per cent Li_2O. Either the theory is wrong or the reported analytical determinations of Li_2O are wrong. A new analysis of this ephesite was therefore made, and 3.80 per cent Li_2O was found, thus confirming the theoretical approach to the correct formula of ephesite.

CO-ORDINATION MODELS

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Models of the atomic structures of minerals have been made by considering the structures as assemblages of co-ordination polyhedra. Tetrahedra and octahedra are the most important co-ordination polyhedra for mineral structures. Close-packed space may be considered as composed of octahedra and tetrahedra, the corners of which may represent the centers of close-packed spheres. The polyhedra are in the ratio of two tetrahedra to one octahedron for every close-packed sphere. For close-packed ionic structures, corners of polyhedra may represent centers of mass of anions, and centers of polyhedra may be occupied by cations or vacant, the proportions of occupied to vacant polyhedra being determined by the chemical formula. In the models, vacant polyhedra are omitted. The method may be extended to nonclose-packed structures. Angles of linkage of polyhedra are regular and determined by inspection. One size of tetrahedral block and two sizes of octahedral blocks are sufficient to build models of the main frameworks of nearly all mineral structures. The models are based on and illustrate the co-ordination theory of Pauling and Bragg.

CHLORITE-CALCITE PSEUDOMORPHS AFTER ORTHOCLASE PHENOCRYSTS, RAY, ARIZONA

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Peculiar dark pseudomorphs after orthoclase phenocrysts occur along fracture zones near the margin of the metallized area at Ray, Arizona. The most intensely altered crystals contain no recog-

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nizable orthoclase but consist principally of chlorite and calcite plus small, but variable amounts of sericite and quartz. Rutile, leucoxene, kaolinite, allophane, hydromica, and sulphides are present in some thin sections.

It is thought that the pseudomorphs were formed by solutions loaded with calcium, magnesium, and iron that moved upward and outward from the ore body where the rocks had been intensely sericitized and the bases other than potassium removed to a considerable degree.

The occurrence emphasizes the problem of the time of alteration. The propylitic stage is often considered to be an early stage, whereas it probably is often a marginal stage that coincides in time with sericitization, or other alteration, near the center of activity. An expanding sericite-quartz stage of alteration may cause those minerals to invade the propylitic rock and thus furnish evidence of an age difference, but in fact propylitization is probably taking place farther out at the same time.

CORONITES FROM THE PRESTON GABBRO, NEW LONDON COUNTY, CONNECTICUT*

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Corona-bearing rocks from the olivine hyperite facies and the troctolite facies of the Preston gabbro are described. Double coronas are present between olivine and plagioclase and between iron ore and plagioclase; single coronas are found between late-magmatic iron ore and plagioclase. The inner shell of the double corona consists of a colorless fibrous mineral (orthopyroxene, anthophyllite, or cummingtonite) that was derived at least in part from magmatic reaction rims of hypersthene that surround the olivine. The outer shell is composed of fibrous actinolitic amphibole that developed partly at the expense of deuteric(?) brown hornblende but mainly by replacement of the adjoining plagioclase. Enigmatic double coronas between plagioclase and iron ore were originally formed between plagioclase and olivine that was later selectively replaced by iron ore. Partly altered magmatic reaction rims of hypersthene surrounded by fully developed outer shells of actinolitic amphibole suggest that the inner shells of many double coronas were formed after the peripheral shells. The single coronas are identical with the outer shells of the double coronas and have the same developmental history.

The coronites grade into more highly altered equivalents in which the outer shells of the double coronas remain intact and the inner shells are replaced by either talc or chlorite and actinolite.

Field evidence does not support Shand's hypothesis of thermal metamorphism as the catalytic factor in corona formation. These coronites are believed to have developed as a result of hydrothermal alteration within a critical temperature range of chemically and mineralogically favorable rocks.

It is proposed that the term "corona" be limited to shells of post-magmatic synantectic minerals. Criteria for distinguishing magmatic from post-magmatic reaction rims based on mineralogical composition and fabric relationships are discussed.

MARINE BEACHES OF THE UNITED STATES

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A reconnaissance of the coasts of the United States was made in order to compare the general character of the beaches in a variety of environments. Preliminary results from this work co-ordinated with more intensive studies of the southern California beaches have helped establish criteria for the recognition of this transitional environment in the sedimentary column. The open beaches are characterized by a relatively high degree of sorting of the sands, a variety of distinctive markings and structures largely related to wave action, a low humus content, selective concentration of particles by

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density, size, or shape, often resulting in bands of dark heavy minerals, and a general broken condition of the shells. Beaches in lagoons and bays on the other hand have much poorer sorting, well-preserved shells, relatively high organic content (often indicated by the black H_2S layer just below the surface), and much less development of wave-produced structures and markings.

In general the widths of beaches vary directly with the size of waves characterizing the area and with the vertical range of tide, and inversely with the grain size of the sands. The foreshore slopes vary directly with the grain size and inversely with the size of the waves. The grain size on the other hand appears to be much more closely related to the source of beach sediment than to wave action.

The mineral composition of the sands provides a fairly reliable means of predicting the general character of the adjacent land mass. Thus the low limestone areas of Florida are surrounded by beaches which have a high uniformity of composition, being mostly quartz in the northern areas and calcareous in the south. The beaches around rivers which drain large and diverse areas have a mixture of the various minerals which can stand transportation. The beaches in glaciated areas and bordering alluvial piedmont plains show the least uniformity in mineral composition. A change of the rock character along the coast is usually accompanied by a change in the minerals in the sand and often by a marked change in the size of the sand grains.

INTERNAL STRUCTURE OF THE SINBAD VALLEY-FISHER VALLEY SALT ANTICLINE, COLORADO AND UTAH

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The Sinbad Valley-Fisher Valley anticline is one of a group of northwest-trending anticlines on the Colorado Plateau with salt cores. Masses of salt, gypsum, and shale from the Paradox member of the Hermosa formation of Pennsylvanian age have intruded Pennsylvanian, Permian, and Triassic sedimentary formations. These intrusive masses were formed in the Permian, but their upward movement continued until Late Jurassic. The resulting structures in turn localized post-Cretaceous regional deformation, which accentuated the old structures and developed broad anticlines in the overlying Jurassic and Cretaceous rocks. The crests of the anticlines subsequently collapsed because of the removal of salt by solution and of the flow of the plastic rocks in the intrusive masses during a late Tertiary to Recent epoch of canyon cutting.

Concentric patterns of folds in the intrusive salt-gypsum masses and the trends of arcuate collapse faults in the rocks above the intrusive masses show that the salt, gypsum, and shale were intruded as roughly circular and elliptical plugs. Individual plugs range from half a mile to about 1 mile in diameter. A large intrusive mass underlying Sinbad Valley is a composite of at least five distinct plugs and is 8 miles long by 3 miles wide. Some of the salt masses of the region have a vertical dimension of at least 10,000 feet.

Along the Sinbad Valley-Fisher Valley anticline, individual plugs and composite masses of salt and gypsum are strung out from half a mile to 8 miles apart like loose beads on a string. These masses are probably connected at depth to an elongate roll of salt and gypsum along the length of the anticline. The separate intrusive masses may be thought of as cupolas extending up from the underlying salt-gypsum roll.

X-RAY DIFFRACTION STUDIES OF SOME PHYSICAL COMPONENTS OF COAL*

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In attempts to determine some of the physical changes that accompany increase in rank in banded bituminous coals, small samples of several of the homogeneous physical components of coal, vitrains,

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fusains, resin rodlets, waxes, cutinite, and spore-exines were isolated and studied by x-ray diffraction techniques. Monochromatic radiation from molybdenum, copper, and cobalt targets was used with a Laue type of camera. The patterns obtained from this method were adequate to evaluate interplanar spacings, particle size, and preferred orientation of particles.

The only diffraction lines given by the vitrains and fusains which are at all sharply defined are the 002 rings corresponding to a spacing of about 3.4 A. All the other diffraction maxima are more or less diffuse haloes of low intensity. All the samples show a large amount of low-angle scattering, partly due to radiation that was not absolutely monochromatic. The diffraction lines given by the resinic components, waxes, and cutinite are much sharper than those of vitrains and fusains and indicate that there is a greater percentage of material in these compounds that is crystalline.

Only tentative conclusions as to changes of structure with increasing rank can be drawn from this preliminary investigation. There is a suggestion from the measured values of the interplanar spacings in the higher-rank coals that the carbon rings tend to approach each other more closely in a direction normal to the 002 planes, the planes in which the carbon rings lie.

REPORT ON THE THIRD CONFERENCE ON CARBONIFEROUS STRATIGRAPHY AND GEOLOGY AT HEERLEN, NETHERLANDS, JUNE 25–30, 1951*

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The program of the Third International Conference on Carboniferous Stratigraphy and Geology held at Heerlen, Netherlands, June 25 to 30 inclusive is briefly reviewed.

Proposals and suggestions of three round-table conferences are summarized. The concensus of the round-table conference on stratigraphy was that the Carboniferous is a unity which must remain classified as a system. It was further proposed that classification of upper and lower parts of the Carboniferous be classified as subsystems. The round-table conference on coal petrography agreed on adoption of two modifications in the system of coal classification: (1) ***Micrinite*** to be distinguished as massive and granular micrinite, (2) ***Sklerotinite*** to be added as a new maceral. A series of proposals and recommendations of the round-table conference on palynology are to be brought to the attention of the International Committee on Nomenclature.

During a post-conference field excursion in west-central Holland, details of relationship of recent peat and marine deposition were pointed out.

STRUCTURE OF THE MAGNETITE DEPOSITS IN THE DOVER DISTRICT, NEW JERSEY

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The magnetite deposits in the Dover district, within the New Jersey Highlands, are Precambrian and replace oligoclase-quartz-biotite gneiss, soda granite, hornblende skarn, and pyroxene skarn. The country rock is deformed into isoclinal folds that trend and plunge northeast.

The deposits in gneiss, soda granite, and hornblende skarn are unusual lath-shaped bodies whose longitudinal planes are essentially parallel to the foliation and whose longitudinal axes are parallel to the lineation in the country rock. Some ore bodies have been mined for as much as 11,000 feet along their pitch length, and the end of an ore body has never been reached. The deposits in pyroxene skarn are probably lenticular or podlike, and they resemble other skarn deposits in the New Jersey Highlands and elsewhere.

The magnetite deposits are linear or curved; they occur on the limbs or in the axial regions of folds. The deposits in gneiss and granite occupy microbreccia zones, which tend to parallel the axial

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planes of the folds and which generally are parallel to the gneissic structure of the country rock, except locally where they cut sharply across it. The microbreccia zones, which were formed by pre-ore cataclastic deformation, were favorable structures for the localization of the ore bodies.

ROCK GLACIERS IN THE NORMAN WELLS AREA, N.W.T., CANADA

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High limestone escarpments along parts of the Norman Range and one outlying mountain are flanked by talus slopes passing down into rock glaciers of exceptional size, extent, and degree of development. The rock glaciers and lower parts of the talus are dark, weather-beaten, locally overgrown by trees, stable under foot, and immobile. Above a line of abrupt color change the talus is fresh, light-colored, and unstable under foot; the upper talus is encroaching on the older deposits below. These relations indicate an earlier and longer episode of talus building and mass movement separated by an interval of stabilization and weathering from a recent, shorter episode of talus building. The interval of stabilization is interpreted to have been due to temporary suspension of effective frost action, and is correlated with the postglacial "climatic optimum." The talus and rock glaciers are thus believed to provide the best record yet found for postglacial climatic change in the region considered.

MORPHOLOGY AND ORIGIN OF LARGE-SCALE AND SMALL-SCALE PEDIMENT FORMS COMPARED

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Miniature mountain ranges and pediments develop abundantly on weak, homogeneous clays of the Oligocene White River formation in parts of the Big Badlands of South Dakota. Within areas as small as 5000 square feet the writer has mapped a complete miniature mountain range with well-developed pediments, pediment embayments, and pediment passes. The general morphology is similar to that of mature mountainous desert regions of the southwestern United States.

Comparison of these miniature forms with landforms of the Sacaton Mountains of Arizona shows that the miniature pediments have steeper gradients than the large-scale pediments, but that the angles of the mountain fronts are about the same for both, averaging approximately 35°.

As in the deserts, there is an abrupt reduction of slope where the miniature mountain front meets its bordering pediment. The miniature mountains differ from large-scale forms in that the drainage is not well integrated, but instead consists of closely spaced rill channels having the same gradient as the mountain slope.

No evidence was observed of small-scale pediment formation by lateral corrasion of discrete streams swinging back and forth over the pediment surface. Instead, the presence of a thin layer of mud over the pediment surface suggests that sheet flood is a major agent of miniature pediment development. Undercutting of mountain slopes, seen along the inner margins of small pediment embayments, indicates some lateral corrasion, which, in the absence of discrete drainage channels, must represent erosion at the margins of a sheet flood.

DIFFERENTIAL THERMAL CURVES OF SOME ARKANSAS LIGNITES

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The differential thermal method was used to obtain curves on 10 samples of Arkansas lignites. A curve of high-purity alpha cellulose was also run. The samples were —100 mesh and diluted with

alumina. Most of the curves had a low-temperature endothermic peak and two exothermic peaks at higher temperatures. In some cases a third exothermic peak was observed.

To verify the theory proposed for explanation of the various peaks, curves were obtained on oven-dried samples and also curves of the lignites under neutral atmosphere.

X-ray diffraction patterns were obtained on the lignites using a Norelco, Geiger-counter type machine.

FUSULINIDAE IN THE PENNSYLVANIAN OF OHIO

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Fusulines were collected from six beds in the Pottsville, Allegheny, and Conemaugh formations in Ohio. Species identifications were made from oriented thin sections of specimens from the material collected. Three genera and nine species have been identified. *Wedekindellina*, a genus not previously reported in Ohio, has been found in the Vanport limestone of the Allegheny formation. *Fusulinella* was found in the Pottsville and Allegheny formations, and *Triticites* in the Conemaugh formation.

Fusuline zones, very similar to those recognized in Illinois, were found in the Ohio rocks. The *Fusulina* zone appears to be missing because this genus has not been identified here.

STRATIGRAPHIC STUDIES OF GRAYWACKES AT DUCKTOWN, TENNESSEE

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The pyrrhotite-pyrite-chalcopyrite ore bodies of the Ducktown Basin are localized in favorable zones in a thick graywacke-schist sequence. The formations have been subjected to at least two periods of folding and are cut by three fault systems.

Graded bedding and poor sorting are characteristic of the graywackes. Medium-rank metamorphism has resulted in transformation of each normal graded bed into a graywacke-schist pair. The coarse clastic material forming the lower part of the bed is relatively unchanged; the finer material of the upper part of the bed has been metamorphosed to a mica schist. In addition to the cyclical repetition of graywacke and schist beds, a larger-scale alternation of dominantly graywacke groups of beds with groups that contain more schist than graywacke is evident. The sulfide deposits lie in zones in which schist is abundant.

Lateral gradation from one rock type to another is common throughout the Basin and is especially prominent in the mineralized areas. This facies change appears to have been an important factor in localizing the ore deposits, probably because of differences in structural behavior of rocks of different competency.

Normal stratigraphic methods have been supplemented by detailed study of heavy accessory minerals. Ilmenite is an abundant constituent of some beds. It is useful in tracing beds in the field and in deciphering complex structures. Minute grains of detrital zircon can be easily distinguished in drill core with the aid of a short-wave ultra-violet light. Zircon logging of drill core is useful in correlating formations cut in diamond-drill holes.

MODERN FOLD IN TEXAS

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About 2 miles west of the town of Paint Rock, Texas, along the road to San Angelo, the gently dipping beds of massive limestone have been deformed into an anticlinal arch. This uplift has an

amplitude of about 8 feet and an axial length of a few hundred feet. The axis trends directly along the center of a stream channel, the water having been diverted to the flanks of the uplift.

Of unusual interest is the report by local inhabitants that the deformation took place entirely within a few days during an unusually high-flood stage of the stream in 1948. No other such disturbances of the sediments were observed in the area.

An analysis of the fractures indicates that the movement took place primarily along pre-existing joints which may be traced into adjacent undisturbed areas. The only fracture developed at the time of arching is a jagged one that marks the crest line.

The origin of this structure may be due to force of volume changes related to hydration of a facies beneath the limestone unit exposed at the surface.

EVOLUTION AND STRATIGRAPHIC SIGNIFICANCE OF THE LATE PALEOZOIC OSTRACODE *CORYELLINA**

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The genus *Coryellina* was established by Bradfield in 1935 with *C. capax* Bradfield, from the Devils Kitchen member of the Deese formation (Pennsylvanian) of Oklahoma, as the genotype. This genus, present in shales, limestones, and sandstones (calcarenites) of Mississippian to Permian age, has a little spine that assumes a continually higher position on the posterior surface of the valve in progressively younger rocks. The validity of the assumption that this phenomenon reflects an evolutionary trend and that the position of the spine can be used in broad stratigraphic determination is supported by more than 100 specimens from nine localities in Texas, Oklahoma, and western Scotland. This genus is present in the Phosphoria formation (Permian) of Idaho and has been recorded in the Chester group (Mississippian) of Illinois. This discovery is important because of its possible use in age determination, but more so as a clue for the investigation of orthogenesis in other ostracode genera.

BIOLOGICAL AND PHYSICAL-CHEMICAL CONDITIONS IN NEWPORT BAY, CALIFORNIA

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Study of Newport Bay shows that the distribution of plants and animals is controlled by various physical-chemical conditions such as tide range, salinity, pH, and nature of sediment. The plants living on the marshes of Newport Bay and other estuaries and lagoons in turn exert a great influence on the sediments. They are the chief source of the organic matter, much of which is preserved because oxygen is absent or low in the interstitial water of the sediments. Where oxygen is absent, hydrogen sulfide forms, and metallic sulfides are deposited. Photosynthesis causes the pH of the water in channels to be high during the day, and respiration causes it to be low at night. Organic acids further lower the pH in the sediments so that calcium carbonate is dissolved. The high organic content, the presence of metallic sulfides, and the low or absent calcium carbonate of marshes is also characteristic of black shales.

* Publication authorized by the Director, U. S. Geological Survey.

GEOLOGIC PROBLEMS IN THE DESIGN AND CONSTRUCTION OF HIGHWAYS IN MICHIGAN

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I. Early experiences which lead to the consideration of geologic factors in Michigan
  1. New bridge in a peat bog failed before it could be opened to traffic.
    (a) Engineers failed to recognize some of the problems in stability associated with marsh deposits.
  2. Several highway sections disappeared into "underground streams and lakes" requiring, for instance, 75,000 cubic yards of embankment materials instead of the estimated 10,000 cubic yards.
  3. Winter frost bump in new concrete pavements requiring warning flares.
  4. Fill settlements and slides
    (a) Failed to recognize basic differences in granular and cohesive material with respect to their influence on construction practices and highway stabilities.
      (1) Cut sections—slopes
      (2) Fills—swamp, upland

II. Steps taken to prevent failures and to take advantage of favorable geologic conditions
  1. Test borings and samples
    Visual examination of foundation materials.
  2. Laboratory tests on samples
    (a) Gradation tests—sieve and bayouces
    (b) Plasticity tests—atterberg limits
    (c) Strength tests—shear tests
  3. Soil-classification surveys
    (a) Sizing up the area—glacial formations and land forms
    (b) Identifying the soil profiles—pedology
    (c) The map—area concept
  4. Making the field surveys and laboratory tests conveniently usable by the designing engineer
    (a) Tabulating answers to design questions
    (b) Reports and recommendations submitted with field maps
  5. Checking plans in the field
    (a) Study the design engineer's interpretations and use of soil-survey information
  6. Subgrade inspection and consultation during construction
  7. Construction material studies
    (a) Inventory of existing sources
    (b) Development of new sources
      (1) Geologic information
      (2) Air photos
      (3) Resistivity surveys

QUANTITATIVE CHARACTERISTICS OF MATURE EROSIONAL TOPOGRAPHY

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The characteristics and variations of morphology of erosional topography in the mature, or equilibrium, stage have been analyzed for sample basins of the third and fourth orders in five regions differing widely in relief, lithology and structure, soils, vegetation, and climate.

Mean hypsometric curves of all five areas are very similar in form and can be satisfactorily described by a simple three-variable exponential function, but the mean subsurface integrals (areas under percentage hypsometric curves) have a range of from 40 to 60 per cent. Probability tests show that the differences in mean integrals are not significant for successive members of the series but are significant for alternate members.

Differences in mean integrals are definitely associated with differences in other morphological characteristics of the five areas. In general, drainage-basin height, slope steepness, and drainage density show a positive correlation with subsurface integrals. On the other hand, no correlation seems to exist between the subsurface integrals and either bifurcation ratios or length ratios. A highly significant correlation exists between mean length of stream segments of a given order and the subsurface integrals of the corresponding areas. The correlation is particularly striking in the case of the mean length of third-order segments, which varies about as the fourth power of the subsurface integral.

A strong positive correlation was found between drainage density and mean angle of valley wall slopes. This tends to verify the deduction that steep-gradient topography favors development of fine texture.

THERMODYNAMIC BASIS FOR A PETROGENETIC GRID

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The lines separating adjacent mineral facies on a pressure-temperature diagram are curves of univariant equilibrium. If the equilibria involve only crystalline solids, in the region of petrologically probable temperatures and pressures, these curves have slopes in accord with the Clapeyron equation and are virtually straight lines. Many equilibria relating to actual petrologic processes, however, involve gain or loss of a mobile constituent such as water or carbon dioxide, acted upon by a pressure equal to or less than that acting upon the crystalline solids. Unless some relationship is assumed between the pressure on each mobile constituent and the total pressure, a new independent variable is added for each such constituent.

If only one mobile constituent is involved in the equilibrium, and the pressure upon it is equal to the total pressure, the Clapeyron equation still applies, producing curves of positive slope, concave toward the pressure axis. This approximates the conditions of most hydrothermal experimentation and geologic processes in which the mobile constituent is produced very rapidly.

Another possibility is to make use of the fact that the mobile constituents should in time acquire a vertical distribution according to hydrostatic equilibrium. In this event the Clapeyron equation must be modified, and it can be shown that, in most petrologically important equilibria, the curves are still concave toward the pressure axis, but with negative slopes. Consideration of these two cases suggests a new approach to the differences between regional and contact metamorphism.

TECTONICS OF A MANTLED GNEISS DOME IN SOUTHEASTERN VERMONT

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In the core of the Green Mountains in southern Vermont Precambrian schists and gneisses are overlain unconformably on the east by metamorphosed strata at least in part of early Paleozoic age. These strata appear to be the mixed volcanics and clastic sediments of a typical eugeosynclinal facies. In much of Vermont these rocks form an easterly dipping homoclinal sequence between the Green Mountains and the Connecticut River. West of Springfield and Bellows Falls this homocline is

modified by a complex structure which has many of the characteristics of a mantled gneiss dome as defined by Eskola. Analysis of the minor structural features associated with the gneiss dome shows that the movement of the central gneisses relative to the mantling strata was vertically upward, and that these strata were stretched and thinned in the process. The minor structures studied include drag folds, rotated porphyroblasts, mineral orientation, slip cleavage, boudinage, and deformed pebbles. The drag folds indicate a shear sense the reverse of that found in a simple anticline formed by lateral compression.

The mantling strata were metamorphosed during the doming and now contain staurolite-kyanite schists and epidote amphibolites. The isograds are symmetrical about the dome. There is no evidence of large-scale igneous activity or extensive regional metasomatism related to the doming.

PLEISTOCENE GEOLOGY OF THE DOOR PENINSULA, WISCONSIN

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The survey of the Pleistocene geology of the Door Peninsula, Wisconsin, completes the mapping of the glacial geology of the Green Bay and Lake Michigan lobes begun by Alden in 1898 and extended to the northwest by Thwaites in 1943. The present report includes results of field work by Thwaites, 1922, by Bertrand, 1935–1937, and by both authors jointly 1948–1951. Maps showing surface geology and topography are based on the 1938 aerial photographs of the Agricultural Adjustment Administration supplemented by soil maps. Vertical control was extended from various older surveys by the authors with a sensitive aneroid barometer. The most interesting feature of the district is the Forest Bed at Two Creeks which was studied in detail by Wilson and its age recently determined by the radio-carbon method. The district includes the northern termination of the famous Kettle Interlobate Moraine. Two substages of the Wisconsin drift are mapped, the Cary and the Valders. Several areas of soil within the Valders area are described where the younger red till is unrecognizable. The authors explain this phenomenon by destruction of the thin mantle of young till through soil-making processes. Evidence of considerable glacial erosion of bedrock is presented.

RELATION OF MICROPEGMATITE TO PEGMATITE AT SAFE HARBOR, PENNSYLVANIA

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At Safe Harbor, Pennsylvania, Antietam sediments containing pegmatite pockets and veins have been intruded by basaltic magma. The sediments vary in composition from compact mica schist strata to more porous arenaceous strata composed of quartz and felsitic minerals. Part of the aureole has been entered by sodic vapors which penetrated readily through the arenaceous strata, less freely through the schist strata and pegmatitic material.

Alteration noted in the biotite-rich schist strata, when caught within the aureole, indicates that there was always a mafic mineral stable under the conditions imposed. Metamorphism of high thermal type follows conventional lines and presents no problem.

Alteration noted in the arenaceous strata suggests that a magmoid condition was reached. There is flow or movement. This magmoid forms fairly large masses of irregular extent with uniform composition. It solidifies to the rock that has been called "pink diabase" and "granophyre."

Result of sodic vapors acting on felsic minerals can be studied to best advantage in the pegmatite veins. Where these have been caught within the aureole, residual cores of orthoclase and quartz (strained) are surrounded by zones of fine-grained micropegmatite, albite, and quartz (straight).

Author's conclusions: Micropegmatite can derive from pegmatite minerals by soda pneumatolysis.

Granophyre or pink diabase, as occurring at Safe Harbor, Pennsylvania, derives from sedimentary strata composed essentially of granitic minerals by soda pneumatolysis.

PRE-HURONIAN GLACIATION AND EARLY HURONIAN WEATHERING AND SEDIMENTATION IN THE MENOMINEE DISTRICT, MICHIGAN

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A 16-mile long strip of vertically tilted tear-faulted Lower Huronian white Sturgeon quartzite of marine origin unconformably overlies an Archean granite gneiss. Where the quartzite is in contact with the gneiss the gneiss is altered to a quartz and sericite rock interpreted to be a metamorphosed quartz and clay regolith that weathered from the gneiss before Sturgeon time.

At four localities along the quartzite-gneiss contact the Lower Huronian white quartzite and the Archean gneiss are separated by upturned structural basins which contain (1) feldspathic graywacke conglomerates, laminated graywackes and slates, quartzites, and slaty quartzites, overlain by (2) nonfeldspathic green sericitic quartzose conglomerates, quartzites, and slaty quartzites.

The gneiss beneath the erosional contact with the feldspathic metasediments is relatively unweathered. One of the graywacke conglomerates appears to be a tillite, and the finely graded-bedded graywackes and slates with rafted boulders appear to be varved slates, suggesting that the feldspathic metasediments are of pre-Huronian glacial origin.

Nonfeldspathic green sericitic quartzose conglomerates, quartzites, and slates resembling the underlying feldspathic metasediments in structure and texture are intercalated with strata of green sericitic quartzite which contain ripple marks and cross beds whose orientations conform to the orientations of similar structures in the overlying white Sturgeon quartzite. These relations suggest that the green nonfeldspathic metasediments are interfingered continental and marine deposits laid down in basins after the pre-Huronian glaciation and before the complete inundation of the area by the Sturgeon sea in early Huronian time.

FOUR SERIES OF ALKALI FELDSPARS

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On the basis of x-ray and optical examination alkali feldspars may be divided into four series—microcline-low albite, orthoclase-low albite, sanidine-high albite, and "high" sanidine-high albite. The first three series usually occur in nature as cryptoperthite, a condition which may be revealed only by x-rays. All specimens (5) examined, which belong to the microcline-low albite series, consist of a submicroscopic intergrowth of nearly pure microcline and pure low albite. The orthoclase-low albite series is also usually unmixed to pure orthoclase and pure low albite of submicroscopic dimensions. Representatives of the sanidine-high albite series are usually completely unmixed to pure potash feldspar and pure soda feldspar; only rarely are they homogeneous. Some optically homogeneous representatives of this series consist of three phases: a potash feldspar, soda feldspar, and an intermediate phase representing the original material still unmixed. Synthetic feldspars belong to the high sanidine-high albite series. Natural alkali feldspars can be converted to homogeneous members of this series by appropriate heat treatment.

Optical properties are given for distinguishing the four series. The changes of optical properties with composition and heat treatment are discussed.

RADON AND THICK SOURCE ALPHA DETERMINATIONS ON DEEP-SEA CORES

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A stainless-steel ionization chamber designed for use with a vibrating reed electrometer gives close to 60 per cent efficiency for radon counting with backgrounds of 15–20 cph. Calibration was carried out with National Bureau of Standards solutions and rocks of certified radium content. The thick source alpha activity of six representative deep-sea core samples from the North Atlantic has been determined at intensity of 10–20 cm. Radon determinations by the direct fusion method have been made on a considerable number of these samples. The results of these measurements will be discussed in terms of the ionium method of age determination and the radioactivity of deep-sea sediments.

EVIDENCE OF EUSTATIC CHANGE IN SEA LEVEL IN THE PENNSYLVANIAN OF THE SOUTHWESTERN UNITED STATES

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Pennsylvanian marine strata in southern Arizona and southwestern New Mexico were deposited in a shelf sea at considerable distance from the nearest contemporary lands, the Zuni-Ft. Defiance uplifts to the north, the Pedernal to the east and a hypothetical land to the southwest.

They consist largely of limestone and shale with varying amounts of chert and with siltstone or sandstone in areas near sources of clastic sediments. The limestones include wave-sorted crinoidal and other shelly types, fusulinid coquinas, biostromes, bioherms, finely laminated aphanitic limestones, massive dark aphanitic limestones, and oölitic zones. The shales are typically light gray, highly calcareous, finely laminated, and unfossiliferous.

Following Rich's new concept that most sediments can be classified as having formed above or below wave base, the Pennsylvanian columns in this region seem to record depths alternating between below and above wave base with an average thickness of 30 feet for an alternation. It is proposed that these alternations record repeated eustatic changes in sea level and that the phenomena here described are genetically related to cyclic sedimentation of the Pennsylvanian in the eastern United States as well as Europe and Asia.

CHEMICAL CHARACTERISTICS OF THE JACKSONBURG FORMATION

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Plots of chemical analyses of the Jacksonburg formation in the dolomite, carbonate, and insoluble diagrams of Gault indicated that the principal zones of the formation could be recognized in the first two diagrams but not in the third. No attempt was made, however, to plot analyses with respect to their position in the sections cut by drill holes. Three concentrations were recognized, a cement rock group, a limestone group, and a dolomitic group. The plots indicated that the SiO_2/R_2O_3, SiO_2/Fe_2O_3, and Fe_2O_3/Al_2O_3 ratios were constant but the CaO/MgO and SiO_2/Al_2O_3 ratios varied.

More detailed plots were made using Mertie's hypertetrahedral faces and grouping analyses according to position in drill holes. All zones of the Jacksonburg, as known, are present in the area chosen for initial study. The plots show distinct concentrations of points in accord with positions in drill holes. Ratios of pairs of constituents agree with those determined in earlier plots.

Where completely developed the Jacksonburg has been divided into an upper cement rock zone and a lower cement limestone zone. Alternating dolomitic and limestone beds below have been considered

as Beekmantown. The earlier plots of Gault suggested that the dolomitic material was more similar to Jacksonburg sediments than to Beekmantown. The present plots support this suggestion. Four groups of points are recognized—a cement rock group, a cement limestone group, a dolomitic group, and a second limestone group. The cement rock group is distinct from the others. The two limestone groups are very similar and can be recognized only where position in the section is considered. The dolomitic group is closely related to the limestone group.

MINERALOGY, PETROGRAPHY, AND PETROLOGY OF THE K-BENTONITES

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A detailed mineralogical and petrographic study of 22 potassium bentonites (metabentonites) from the Ordovician of central Pennsylvania revealed that they are composed of randomly interstratified layers of nonexpanded, K-based montmorillonite and expanded Ca-, Mg-, and Na- based montmorillonite in the approximate ratio of 4:1. Several of the clays contain a small amount of chlorite in the form of packets. Chlorite is the cause of one of the two hydroxyl-endothermal reactions in this material and is probably responsible for one of the peaks of similar double reactions which have heretofore been assigned to the individual mineral components of mixed-layer clays.

A study of 27 samples of the limestone above and below the K-bentonite showed that the rock in immediate contact contains the same types of clay. However, farther from the beds the clays consist of three, unmixed-clay minerals: nonexpanded montmorillonite (illite), expanded montmorillonite, and chlorite.

It is thought that the criteria for the division of clays of the 2:1 structure type into two groups are not fundamental, and the suggestion is made that these clays be classified on the basis of the chemical composition of the impure pyrophyllite-talc structural unit rather than upon the characteristics which are a direct reflection of the interlayer cations.

The K-bentonites contained angular volcanic glass and albite, idiomorphic apatite, zircon, and biotite. The limestones contain idiomorphic quartz, albite, apatite, zircon, and xenomorphic biotite.

FAULTED PALEOCENE OF RIDGE BASIN, CALIFORNIA

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Ridge Basin, a tilted graben, geologically part of the Ventura Basin, southern California, lies between the Clearwater and San Gabriel faults. Ridge Basin includes Paleocene marine deposits which appear related to those of the Ventura Basin, from which Ridge Basin seems to have been separated in the Miocene. The Paleocene consists of basal marls, resting nonconformably on crystalline basement, succeeded by boulder conglomerates, black shales, and massive brown sandstones alternating with thin brown shale. The section has a maximum thickness of 11,000 feet. The lower 3000 feet of section is richly fossiliferous, but only small fragments of carbonized wood have been found to date in the sandstones. The Paleocene is horizontal where resting unconformably on the basement in the northwestern part of the basin. Regional dips elsewhere vary from 65° to 85°S. with strikes of N. 75°–80°E. Some overturning occurs in the easternmost part of the section with 85-degree reverse dips. The Paleocene is faulted against Sespe red beds along the Bee Canyon fault and is overlapped nonconformably by a Modelo (Neroly) marine section.

The major structural feature of the northern margin of the basin is the Clearwater fault, along which strike-slip movement up to 2 miles has been suggested (Clements, 1937, p. 212–232). Paleocene sedimentary relations suggest that the observed migration of contacts may be explained by assuming no important strike-slip component, proposing only dip-slip rotational movement on a hinge-type fault.

PLEISTOCENE STRATIGRAPHY IN NORTHEASTERN OHIO

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As part of co-operative ground-water investigations by the U. S. Geological Survey and the Ohio Division of Water, surface mapping of glacial drift in the Allegheny Plateau in northeastern Ohio shows a 2- to 5-mile belt of Illinoian drift across the central parts of Stark and Columbiana counties; an area of coarse-textured early Wisconsin till in southern Summit County, surrounded by later drift; later Wisconsin sandy till in Columbiana, southern and eastern Mahoning, eastern Trumbull, central and southwestern Portage, southern Geauga, southern Medina, and Wayne counties; and still later (in part Defiance and in part just pre-Defiance) clayey till to the north. These drifts are of the Grand River and Killbuck lobes; the boundary between the lobes extends approximately north-northeast from the southwestern corner of Portage County into Geauga County. Weathered Illinoian till underlies fresh Wisconsin till at outcrops in Columbiana, Portage, Cuyahoga, and Mahoning counties. Fresh Wisconsin sandy till unconformably underlies later Wisconsin clayey till at outcrops in Mahoning, Portage, Cuyahoga, Geauga, and Medina counties. At one location in northwestern Portage County earlier sandy till of the Grand River lobe is overlain by later clayey till of the Killbuck lobe, the origin of each from its respective lobe being proved by till-fabric orientation. Tills of more than one Wisconsin stage, as well as pre-Wisconsin tills, appear to be penetrated in water wells, but a precise determination cannot be made until cuttings from wells in critical areas have been obtained and studied.

VACUUM DIFFERENTIAL THERMAL ANALYSIS OF COAL

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Samples of 15–100 mgs. of various coal constituents were used for differential thermal analysis in vacuum and were heated at the rate of 20°C. per minute.

The thermograms are thought to present a graphic representation of some of the physical changes that take place during the carbonization process. Most constituents show an exothermic peak in the carbonization range. The temperature at the beginning of the peak is considered to be the softening point of the coal, while the temperature at which the peak reaches a maximum is thought to be the solidification point. The softening temperature is often made obscure by an effect which is inherent in the instrument.

A comparison of the temperatures at which vitrain peaks attain a maximum gives a measure of their relative rank—that is, the higher the temperature at which the maximum of the peak occurs the higher the rank. This relation is illustrated by a series of curves from lignite to semianthracite.

Analyses of vitrains from columnar samples of the Harbour and Emery seams in Sydney, Nova Scotia, reveal that there is no change in the temperature at which the peaks reach a maximum for bands of vitrain within each sample, but temperatures for samples from the Emery seam are from 10°C. to 20°C. higher than for those from the Harbour. The Emery seam is stratigraphically below the Harbour.

A comparison of the curves obtained from vitrain, spores, clarain, resin, and fusain is also shown.

SOME RECENT CORRELATIONS OF INDIANA COALS

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Various local names have been applied to the Indiana coals since 1850. As early as 1898 G. H. Ashley attempted to correlate these coals from one mining district to another, but owing to lack of

information many errors were made. Later Ashley and other workers made tentative correlations, still without sufficient evidence, and in many cases with conflicting conclusions.

Recent stripping has exposed excellent stratigraphic sections which, coupled with recent drilling information, have made exact correlations possible. This paper deals with correlations of Coals V, Va, Vb, VI, and VII across Indiana. Coal V, with the overlying black fissile shale and Alum Cave limestone, is an excellent and continuous key horizon, but the younger coals vary considerably from one mining district to another.

THIRD HEERLEN CONGRESS OF CARBONIFEROUS STRATIGRAPHY AND GEOLOGY

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The meetings of the Third Congress of Carboniferous Stratigraphy and Geology were held in Heerlen, The Netherlands, June 25 to 30, 1951. North American geologists will be especially interested in the discussions relating to the principal recommendations of the Congress. These recommendations are to be submitted to the next meeting of the International Geological Congress in Algeria in 1952. Briefly stated, they are: that Carboniferous should be retained as a system and that the Congress in Algeria consider adding the category subsystem to the formal nomenclature to accommodate such terms as Upper and Lower Carboniferous and Mississippian and Pennsylvanian. Other topics of interest were the discussions of the uncertainties expressed at the Congress regarding the location of the upper boundary of the Carboniferous and of miscellaneous items affecting methods of correlation and concepts of stratigraphic units.

UNDERCLAY LIMESTONES*

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Within the past 8 years, more than 300 diamond-drill holes, coring Pennsylvanian strata, have been studied by members of the Coal Division of the Illinois Geological Survey. One of the interesting features observed has been the marine limestones that sometimes occur beneath the underclay at the position of the underclay limestone. Often the lower part of the underclay contains small limestone nodules which increase in number and size until a solid limestone bench is developed.

These limestones have been examined megascopically and microscopically to determine the variation in the lithologic and faunal content. Several of these limestones contain well-developed marine faunas, including fusulinids and crinoids. A study of the depositional and ecological environment of underclay limestones is necessitated as a result of the occurrence of the marine faunas.

TAXONOMIC POSITION OF *PANTYLUS*

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Preparation of cranial and postcranial material of the Permian tetrapod *Pantylus* has progressed sufficiently to indicate that *Pantylus* belongs to the cotylosaurian reptiles and not to the microsaurian amphibians, as has been recently proposed.

Specimens in the collection of the Bureau of Economic Geology, The University of Texas, from the Wichita of Archer County, Texas, show the following morphological features to support this view: (1) presence of two bones, probably the postparietal and tabular on the posterior surface of the skull; (2) digits 5, 4, 3, 2, with suggestions that 1 had been present on the manus; (3) ribs holocephalus

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and the capitulum intervertebral; (4) chevron bones present; (5) neural arch somewhat expanded and separated from the centrum by a suture in the caudal region. Intercentra apparently cartilaginous.

BLISTER HYPOTHESIS AND THE PETROGENIC CYCLE

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Many writers have suggested that magmas are the direct result of radioactivity. The Blister Hypothesis would suggest that all magmas are directly or indirectly the result of this process and are derived from previously existing solid rock. Since a Blister is a relatively warmer and expanded subcrustal sector, any level within the Blister may become magma under proper conditions of pressure. It is assumed that some differentiation but almost no convection takes place in the Blister when it becomes sufficiently warmed to form a fluid phase. The particular magmatic type which develops depends principally upon the nature of the rock which is transformed into magma and upon the extent of that transformation. Above the roof of the Blister where plateau flows are apt to form, the sequence of magmatic types is thought to result from the formation of magmas at various levels in a layered crust, although some magmatic differentiation certainly obtains. Hybrid magmas result from the transformation of unusual parent rocks or from mixing during translation and emplacement of magmas from nonhomogeneous sources. Geosynclinal sectors are apt to yield rather pure femag pretectonic magmas, variable but usually silicic concordant tectonic magmas derived from the transformation of sediments, and hybrid discordant post-tectonic magmas. The latet post-tectonic magmas are apt to be of deep-seated origin and femag in character. It is assumed that the presence of Blister makes such petrogenesis possible, not only through its provision of heat but also through its provision of forces sufficient for orogenesis.

UNIT CELL OF SCHAIRERITE

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The unit cell of schairerite [$Na_3SO_4 \cdot Na$ (F, Cl)] has been re-examined in an attempt to reconcile x-ray with morphological data.

Results: Lattice mode—hexagonal—P—not rhombohedral
Crystal class—3 2 or $\bar{3}$ 2/m
Space group—C312 or C$\bar{3}$1m
Cell—a_0 7.05; c_0 19.33; c_0/a_0 2.742
Morphological linear ratio—c = 2.7634 (Foshag); c = 2.752 (Wolfe and Caras)
Specific gravity—2.60 calc.; 2.612 (Foshag); 2.63 (Wolfe and Caras)
Cell contents—7 [$Na_3SO_4 \cdot Na$ (F, Cl)]

Morphological, x-ray, and chemical data are internally consistent.

CRYSTALLOGRAPHY OF JADEITE (?) FROM NEAR CLOVERDALE, CALIFORNIA

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Good crystals of jadeite (?), a few of them doubly terminated, have been discovered by Dr. John Peoples of Petaluma, California, along the Russian River near Cloverdale, California. An analysis is being prepared. Optical data: α1.652, β1.658, γ1.663 all $\pm$ 0.003; positive; 2 V = 70°, 2E = 125°; elongation positive; nonpleohroic; extinction angle z $\wedge$ c = 34°; y = b. Morphology: a:b:c = 1.067:1:0.584; β = 108°20′. Forms: {110}, {111}. X-ray data: a_0 9.51, b_0 8.64, c_0 5.25 kX; β 108°10′; space group C 2/c.

OPAL CEMENT IN THICK TERTIARY EOLIAN SANDSTONE, CHUSKA MOUNTAINS, ARIZONA-NEW MEXICO

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The Chuska Mountains, located along the Arizona-New Mexico State line north of Gallup, New Mexico, are made of the Chuska sandstone, a Tertiary eolian formation which rests unconformably on the eastward-dipping Mesozoic rocks of the Defiance monocline. Eolian deposition is indicated by (1) uniform texture in fine-sand size, (2) high degree of sorting, rounding, and sphericity, (3) absence of shale or of conglomerate except in the basal beds, and (4) high-angle tangential cross-bedding, in units 5–25 feet thick, throughout the 1900 feet of maximum thickness of the formation. Eighty-five per cent of the cross-bedding measurements show dips in the northern hemicircle, suggesting southerly winds.

The clastic grains consist of quartz (60–85%), feldspar (15–35%), chert (1–5%), and heavy minerals (1%).

The cement consists of banded opal and chalcedony rimming uncorroded clastic grains in varying proportions, with large quartz crystals filling the very centers of some of the original pores. The zeolite heulandite appears locally as tiny laths in the cement.

It is proposed that this unique cementation was controlled by a periodically rising water table in an area of accumulating dunes in a desert basin, with the stillstands producing cemented zones 25–100 feet thick separated by weakly cemented zones, all cross-bedded. The abundant silica in the ground water may have had a source in the weathering of volcanic rocks (long since completely eroded) on the margins of the basin. That the cementation is not related to the patches of Pliocene (?) volcanics in the area is seen by the occurrence of these volcanics in deep valleys cut into already cemented sandstone.

PHYSIOGRAPHIC RECONNAISSANCE IN IRAQI KURDISTAN

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From the desert plain of Mesopotamia to the high Zagros Mountains on the Iraq-Iran frontier in Kurdistan is a series of anticlinal ridges of ever-increasing structural and topographic height. In the outer structures are preserved deformed Miocene and Pliocene red beds and conglomerates, which were derived from the Mesozoic and early Tertiary limestones of the high mountains and represent the culmination of the Alpine orogeny.

The basins or plains between the ridges are etched in softer rocks and reveal broad pediments of several stages. The longitudinal subsequent streams to which these surfaces are graded are tributary to the transverse master streams that flow from the heights of the Zagros Mountains to the Tigris River on the Mesopotamian Plain. Near the mountains the pediments bear only a thin cover of coarse gravels, but distally the surfaces are buried beneath 30–150 feet of fluvial silts. The buried pediments are now locally dissected by a multiple gully system 100–200 feet deep which records epicycles of alluvial cut and fill.

The basin areas are extensively farmed and grazed by primitive methods which may not have changed greatly in the last 4000–7000 years. The area now has 12–25 inches of winter rain, but the intense heat and dryness of the summers reduce productivity.

One of the objectives of the field work, which was supported by the Wenner-Gren Foundation for Anthropological Research, the Oriental Institute of the University of Chicago, the American School of Oriental Research and the University of Minnesota, was to prepare a framework of Pleistocene physiographic and climatic changes in the foothills border of Mesopotamia, where the agriculture may have been born which later expanded to nurture the great Mesopotamian civilizations.

Current excavations at three sites (Middle Paleolithic, Mesolithic, and "Neolithic") and collections from terrace surfaces and alluvial fills may all be fitted into the framework, which was controlled partly by continued uplift of the mountain belt and partly by climatic changes.

STABILITY RELATIONS OF CLINOCHLORE AND CORDIERITE IN THE SYSTEM $MgO—Al_2O_3—SiO_2—H_2O$

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Equilibria in a portion of the system $MgO—Al_2O_3—SiO_2—H_2O$ have been determined at temperatures from 450° to 900°C. at pressures of water vapor up to 30,000 psi. The univariant pressure-temperature curves have been bracketed for the following reactions:

Clinochlore $\rightleftharpoons$ forsterite + cordierite + spinel + vapor

Talc + clinochlore $\rightleftharpoons$ forsterite + cordierite + vapor, and the reactions in the $MgO—SiO_2—H_2O$ system investigated by Bowen and Tuttle (1949) are confirmed.

Pure clinochlore has a maximum stability limit of 680°C. at 15,000 psi. water vapor pressure. Below about 550°C. a new form having the clinochlore composition is obtained. It is suspected that this form, although its stability has not been fixed with certainty, may be isostructural with one form of serpentine.

Cordierite is stable at least as low as 510°C. in the presence of water vapor. Pyrope was not synthesized, and it is concluded that it is not stable in the presence of an excess of water vapor in the temperature range investigated. Amesite and magnesium chamosite were not produced. The metastable formation of the phases mentioned above is common, and their reaction rates are very slow.

It can be demonstrated that several common hydrothermal alterations which have been interpreted as retrograde metamorphism, in the sense of lower grade, need not mean a change in pressure or temperature conditions, but may mean access of water vapor. The presence of an "excess" or "deficiency" of water vapor greatly influences the mineralogy of a metamorphic rock.

NEW DETERMINATIONS OF GEOLOGIC AGE BY THE THERMOLUMINESCENCE METHOD

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A series of new geologic age determinations by the thermoluminescence method have been run. These determinations were specifically designed to test the accuracy of the method and to determine its usefulness in dating geologic events. New methods have been devised for checking results so that relative error may be reduced. The basic theory of the thermoluminescence method of age determination has been more thoroughly tested, and the behavior of the time curves is more fully known.

Limestone samples have been collected in stratigraphic sequences to test the absolute accuracy of the time calculations. Samples of limestone and calcite have also been collected from faults, contact zones near dikes, metamorphosed zones, and crypto-volcanic structures in order to attempt to date these geologic events. Any geologic process which causes limestones to be recrystallized is capable of being dated by the thermoluminescence method. Where unmetamorphosed limestones of the same formation are available, direct comparison between the age of recrystallization and that of the original sediment can be made.

Through the use of a large number of stratigraphically controlled samples it is possible to improve the accuracy of the crystal-lattice constants of calcite. It is also possible to establish both theoretical and experimental time curves. Through the comparison of these curves, it is hoped that information for the more accurate establishment of standards of geologic time may be obtained.

ABSTRACTS OF PAPERS SUBMITTED TO THE APRIL MEETING IN LOS ANGELES, MARCH 23–24, 1951

CORDILLERAN SECTION

TUMAC MOUNTAIN, A POSTGLACIAL CINDER CONE IN WASHINGTON STATE

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Tumac Mountain is a breached postglacial cinder cone in the Cascade Range of west-central Washington approximately 22 miles southeast of Mt. Rainier. The elevation of the rim of the cone is 6300 feet. The low point in the crater lies 400 feet below the rim. The total height of the cone is roughly 700 feet above its base.

The cone is composed of volcanic bombs, lapilli, tuff, and ash which form alternating reddish and black layers dipping away from the crater. The composition of the ejecta is basaltic. Principal minerals which are imbedded in volcanic glass are labradorite, olivine, hypersthene, and augite.

The Tumac cone rests on a high plateau capped by early Pleistocene vesicular basalt. Numerous criteria indicate that the plateau was subjected to a severe alpine type of Wisconsin glaciation. Because the cone shows no effect of glaciation it is clear that it is post-Wisconsin in age. Tumac is believed to be the first volcanic unit to be reported in the State of Washington that commenced and ran to completion in post-Wisconsin time.

LATE PALEOZOIC REEF SEQUENCES IN WEST TEXAS

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Reef studies in the Pennsylvanian and Permian seaways of the Southwest show several types of reefs and associated limestone buildups and indicate the sedimentary controls for their formation. The seaways were wide, the sea floors highly irregular. Limestone buildups grew on the shallows. Minimum supplies of mud were deposited in the surrounding deeps. Common buildups include reefs, banks, and platforms. Reefs are characterized by narrow crests and hundreds of feet of topographic relief. The term includes both wave-resisting growths and structures of similar size and shape that developed near or below the base of wave action. Many isolated growths of the central seaways were drowned by rapid subsidence. Muds buried the shoreward growths. Recurrent warpings rejuvenated many of the drowned buildups, but the leveling of the marginal areas in late Pennsylvanian and early Permian produced extensive bedded limestone terrains with reef growths along their seaward edges. The linking of these bank margin reefs produced the segregating barriers of the Middle and Later Permian. Special sedimentary studies to predict the presence of undiscovered reefs have not as yet been extensively applied.

ARROYO CUTTING AND FILLING

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The main common factor of past and present arroyo (channel) cutting and filling is the condition of the plant cover. Channel erosion takes place when the water from torrential rains runs off too fast because the plant cover and soil mantle have been impaired or devastated. Such destruction was in the past caused by drought, during the last 100 years mainly by overgrazing, trampling, and forest cutting. The opinion that also the modern gullying, which began in the 1880s, was caused by a "change of climate toward drier conditions" is not backed by any evidence that the initiation was preceded by a marked increase in aridity. Whether or not the severe drought of the past several years in the Southwest would have set off gullying under virgin conditions is difficult to judge. The opposite view that all old buried channels are results of erosion and filling under "natural" or "normal" conditions is based on unfamiliarity with the amplitude of past climatic changes, overrating of torrential rains, and underrating of the plant cover.

While temporary deposition takes place normally between big flash floods, permanent arroyo

filling postulates a vegetation competent to prevent violent sweeping floods. Soil formation on flood-plain fill takes place when vegetation is sufficiently dense also on uplands to prevent sheet erosion and to absorb much water so that floods are small and carry little mud.

Normally past arroyo erosion means a dry age, buried soils relatively moist ages, and rapid arroyo filling transition.

FOUNDATION AND ABUTMENT TREATMENT—MCNARY DAM, OREGON AND WASHINGTON

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The construction of McNary Dam, a multipurpose project on the Columbia River 292 river miles above its mouth, is currently being advanced under supervision of the U. S. Corps of Engineers.

Foundation for most of the dam and its appurtenant structures is a series of gently folded basaltic lava flows representing a part of the Columbia River basalt of Miocene age. In general, these provide an excellent water-tight, strong type of foundation as indicated by extensive subsurface testing during design studies and excavation exposures during construction. The south (Oregon) abutment of the dam is composed of a deposit of gravels laid down in late Pleistocene time by glacial melt waters to a maximum depth of 190 feet.

Necessary treatment of the foundation and abutments is restricted to: (1) grouting and drainage of areas in which uplift, after the reservoir pool is raised, might become critical if not done; (2) consolidation area grouting of local minor faults and fractured sections; (3) "broomed" mortar filling of fractured surfaces and dental treatment of local depressions with 1½-inch concrete; and (4) the construction of an upstream impervious blanket and down-stream drainage facilities to minimize the possibility of deleterious effects from seepage through the gravel of the south abutment.

ANGIOSPERMS GRADUALLY ASSUMED DOMINANCE

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The belief that angiosperms rose to dominance with "bewildering suddenness" during Cretaceous time has been widely accepted for well over 125 years. This "fact," regarded as "one of the most remarkable phenomena of biological evolutionary history," finds its roots in the catastrophism of the last century and apparently derives no support from the geological record.

Data are presented to show that the time (in millions of years) required for other major groups (classes, phyla) to rise to dominance parallel that indicated by angiosperms. Furthermore, the angiosperm flora rose to dominance during an interval which agrees closely with that of the other major floras which had preceded it.

The conclusion seems warranted that angiosperms must be removed from the category of "miracle plants." They gradually assumed dominance in lowland areas several tens of millions of years after they first appeared in the record. Such a history is not unique but is paralleled by most other groups of vascular plants.

STRATIGRAPHY OF A PLIOCENE VERTEBRATE FOSSIL LOCALITY NEAR PRESCOTT, ARIZONA

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A Lower or Middle Pliocene vertebrate fauna has been excavated from fluviatile deposits near Milk Creek in the Walnut Grove basin, 20 miles south of Prescott, Arizona.

Basin-filling sediments attain a minimum thickness of 1000 feet. Fine- to coarse-grained sandstones, locally containing cross-stratified units up to 60 feet thick, constitute most of the beds. Claystone, siltstone, and granule conglomerate are present to about 15 per cent. The sequence is capped by 200 to 300 feet of cobble and boulder conglomerate. Tuff beds occur in the lower and middle portion.

The sedimentary rocks of the basin dip east and northeast, with minor reversals at the edges close to the basement, except in the northwest part where the beds dip west at low angles. A greater proportion of coarse sediment in the beds toward the north indicates a northern source for most of the material. Cobbles and boulders in the conglomerates are composed of granitic and metamorphic rocks of the basement, with lesser quantities of basalt and dacite, but no sedimentary rocks.

The basin is bounded on the north and northeast by metamorphic rocks and on the east and south by granitics. To the west, lavas and alluvial fill mask the basement rocks. Black Mountain, a granitic hill in the South-central part, has a veneer of dacite and younger basalt on its top and northern slopes. These lavas interfinger with the fluviatile sediments, providing relative dating for part of the volcanic activity of the Prescott region.

GULLIED SUBMARINE SLOPES OFF SOUTHERN CALIFORNIA

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Echo-sounding profiles off the Southern California coast show small channel-like features trending down slope. These are here termed *sea gullies*.

Controlled surveys have been made of sea gullies off the town of San Clemente. Here they have V-shaped cross sections, especially near the break-in-slope of the continental shelf (47 fathoms) where they originate. Some develop flat bottoms as they approach the local basin floor (400 fathoms). Wall declivities are as much as 17° and slopes 10°. Maximum relief is 40 fathoms. The sea floor is largely fine sediment with local areas of coarser material. Under-water photographs show current ripples at depths of 104 fathoms.

Over-heightened channel banks, suggesting natural levees, have been noted in sea-gully crossings both at San Clemente and other localities off the California coast. Sea gullies are found at depths up to 750 fathoms and in one place at 100 fathoms below the sill of a closed basin.

Sea gullies differ in many respects from the much-discussed submarine canyons, but a genetic relationship is possible and is discussed. Channel-like features with cross sections similar to sea gullies in practically all size ranges are found in other localities off the west coast of North America.

It is believed that sea gullies are of marine origin; possible modes are discussed, including formation by erosion or by differential deposition. Special attention is given to the idea of erosion by turbidity currents.

TRANSPORTATION OF COARSE MATERIAL ON ALLUVIAL AANS

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Movement of large quantities of coarse material down slopes of alluvial fans by mudflow transport was convincingly demonstrated by Blackwelder in 1928. In other cases torrential rains on arid and semiarid mountain ranges cause water floods down their canyons and on the fans at their mouths. Contrary to usual conceptions the upper parts of many large fans are not continuously aggrading, as pointed out by Eckis. Often the building stream is entrenched to a depth of feet or tens of feet for a quarter or half of its radial length down the fan. Because the stream on the upper part of a large fan is in approximate equilibrium such trenches presumably are cut and refilled frequently. In such channels water floods, as well as mudflows, can handle very much coarser rock debris than they can transport on the relatively smooth surface of the fan.

This paper points out that the frequent intrenchment of streams on fans is a very important, if not controlling, factor in movement of very coarse material to the middle or lower parts of the fan surfaces, whether by mudflow or water flood.

GEOLOGY OF THE GLEN CANYON GROUP BETWEEN LEES FERRY AND TUBA CITY, ARIZONA

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The Glen Canyon group has been mapped from Lees Ferry to Tuba City, Arizona, in the western sector of the Navajo Indian Reservation. The formations constituting this group, of probable Jurassic age, are the Wingate sandstone, the Kayenta formation, and the Navajo sandstone, all of continental origin.

An erosional unconformity separates the Glen Canyon group and the underlying Chinle formation. This contact is mappable throughout the area. In the walls of Moenkopi Wash, it consists of the cross section of a stream channel cut in the Chinle formation and filled with cobbles and pebbles. Immediately overlying these deposits is a thin pebble conglomerate which was traced northward 60 miles to Lees Ferry.

Above the basal conglomerate at Moenkopi Wash the group is dominated by slope-forming Kayenta-type rocks. Two tongues of Wingate sandstone are present in this area totalling less than 80 feet. At Lees Ferry, however, the basal conglomerate is overlain by over 400 feet of cliff-forming Wingate sandstone, and the Kayenta formation is represented by two thin tongues totalling less than 50 feet. Thus, the evidence seems to indicate that Kayenta-type rocks intertongue with the Wingate sandstone, and that these rocks represent a facies change involving two distinct environments of deposition.

The Navajo sandstone overlies the lower formations of the group. The contact between the Navajo sandstone and the underlying rocks is believed to be a surface of erosion in this area. Locally a basal conglomerate occurs.

CAMBRIAN HIGH IN EASTERN NEVADA

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The segment of the Snake Mountains lying north of Sacramento Pass in eastern White Pine County, Nevada, is essentially a large dome, the core of which is composed of Precambrian quartzites, interbedded schists (3500 feet +), and older gneisses, schists, and pegmatites. Unconformably, above the Precambrian crystalline rocks is a conformable sequence of sedimentary rocks having the following characteristics and approximate thicknesses, beginning with the oldest: thinly bedded, relatively pure, pink to brown unfossiliferous quartzite, 250 feet; dark-gray to greenish-gray shale, 90 to 200 feet; thinly bedded, gray to light-gray, fossiliferous limestone, 1800 feet. B. F. Howell reports that fossils collected from near the base of the limestone are of early Ordovician age approximately equivalent to the Pogonip or Tank Hill formations of Nevada. Relatively thick sequences of Ordovician, Silurian, Devonian, Mississippian, Pennsylvanian, and Permian strata occur above the Lower Ordovician limestones.

Stratigraphic and structural evidence indicates that, during Cambrian time, the present area of the Snake Mountains was relatively high; consequently, there is no thick Cambrian section such as is present elsewhere in this region.

The domelike symmetry of the range is locally broken by a large, very sharp, asymmetrical and locally overturned fold that extends south-eastward from the central part of the range to its southeast margin. This fold is overturned to the west and has been tentatively interpreted as being due to high-angle thrust faulting in the crystalline rocks which folded the overlying sedimentary rocks. Many minor folds and other faults are present near the crest and along the margins of the range.

EVIDENCE OF PLEISTOCENE MAN IN DEATH VALLEY, CALIFORNIA

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The former presence of a Pleistocene lake in Death Valley has long been known. Blackwelder, who first discussed the lake in detail, believed it to be of Tahoe (early Wisconsin) age. A broad terrace in

the central part of Death Valley, not heretofore mentioned in the literature, suggests a long stand of the lake 300 or 400 feet below the highest level reached. It seems logical to correlate this stand with the Provo stage of Lake Bonneville, which has been called Tioga (late Wisconsin).

The surface of the terrace is floored with a typical desert pavement, among the rocks of which the junior author found one that bore unmistakable signs of human workmanship. Intensive search resulted in the finding of several hundred more artifacts. The implements are all of crude workmanship, generally uniface, and made of local materials: rhyolite, red jasper, green chert, and chalcedony. The absence of obsidian implements is striking. Scrapers constitute the most abundant type of artifact, but crude blades, gravers, and a few choppers were also found.

The artifacts are integral parts of the rock pavement, of the terrace, and like the other rocks are heavily patinated with desert varnish. Many also show wear by water. The evidence suggests that they were in use when the lake stood at this level, and therefore that man was present in Death Valley during the Pleistocene at least as early as Tiogan time.

FACIES RELATIONSHIPS OF REEFS*

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Subequidimensional organic reefs known as reef knolls, and similar structures called bioherms, indicate growth in relatively quiet waters such as those of lagoons, protected banks, or below vigorous wave action. Such structures generally grade abruptly to adjacent sediments.

Strictly linear types of reefs—fringing reefs, barrier reefs, and atolls—are typically wave-fronting structures. The growth forms of their organic elements are characteristically stout and commonly crustose, and delicately branching forms are rare or absent in parts of the reef that are exposed to strong wave action. Seaward the linear reefs grade through reef talus to enveloping sediments. The degree of mixing or diffuseness of contact is related to source and sedimentary environment of offshore deposits and slope of reef front. Fringing reefs may be expected to grade abruptly to the surface which they veneer, and both the reef proper and its offshore talus slope may contain variable amounts of land-derived detritus. Barrier reefs and atolls may be expected to show complex relationships with lagoonal sediments and biohermal structures behind them. Table reefs are lagoonless reef masses of the open ocean.

Ancient reefs commonly differ significantly from modern ones. The Permian Capitan reef (a barrier reef) probably resulted primarily from algal growth and physiochemical precipitation of calcium carbonate. Massive, nearly structureless Cambrian bioherms in central Texas probably resulted from the calcium precipitation and sediment-binding activities of algae. Other structures called reefs may be depression fillings, or banks of triturated organic materials that were held together as they piled up by concordant deposition of surrounding sediments.

GEOLOGY OF SAIPAN, MARIANA ISLANDS†

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Saipan is one of the larger, southern islands of the Mariana-Bonin arc. East of and parallel to this arc is a deep submarine trench, and then the Pacific Basin proper. Westward lies the Philippine Sea, considered a submerged portion of the Asiatic structural block. Very recent changes of sea level have affected the Island.

Saipan consists of a volcanic core enveloped by younger limestones. It began its known geological record in Eocene (?) time, with the subaerial accumulation of dacitic volcanic rocks. Andesitic volcanics were subsequently added to the island mass, and equivalent and overlying Eocene marine deposits resulted from reworking of volcanic sediments. The lower 4100 feet of Saipan's composite geologic section is of volcanic origin, comprising, in ascending order, the Sankakuyama, Hagman, and Densinyama formations. The Mariana-Bonin arc, as a structural feature, may well have orig-

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inated concomitantly with Eocene volcanism. It is at least as old as Eocene, but there is no known evidence to support that it is older.

The volcanically derived rocks are succeeded by approximately 2100 feet of dominantly clastic limestone and some unconsolidated sediments of Eocene, Miocene, and Pliocene to Recent age, most of which accumulated in shallow tropical seas. The Eocene Matansa limestone and Miocene Tagpochau limestone seemingly represent bank-type deposits, not associated with significant coral-reef masses. The younger deposits of the Tagpochau limestone overtopped the volcanic core of the island, and for a part of early Miocene time there was no land within the area of present-day Saipan. A variety of intergrading facies characterizes the older limestones. The post-Miocene limestones are comparable to lagoonal and reef-limestones being formed in shallow water about Saipan today.

SOUTHERN CALIFORNIA COASTAL PALEOGEOGRAPHY

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Economic interest induced premature extension of onshore paleogeographic studies to submerged part of the continent off Southern California coast. A set of paleogeographic outline maps is presented including: Eocene, Oligocene, lower, middle and upper Miocene, Pliocene, and one of basement areas and major structures, all on contoured base map.

Broad Eocene land and sea features were broken in detail by Oligocene deformation and emergence, but the general plan existed into lower Miocene. General submergence progressed through middle and upper Miocene over a very irregular terrain, with basin and range structural pattern, creating many islands or banks. New general deformation changed Miocene outlines, with new Pliocene emergences and deepening of basins as onshore.

Reversal of vertical relations between blocks and great lateral offsets occurred in the offshore area, some in Miocene, as onshore.

All available lithologic data for the submerged area, as yet very scant, have been used in this study. Most is from Shepard and Emery, as is the base map. Correlations were made through coordination of all methods on detail charts.

Interpretation of the offshore area's history, admittedly imaginative, was guided also by knowledge of similar situations onshore. The outlines are subject to revision pending solution of several problems of submarine processes in such situations and conditions. For example, actual emergence of many positive areas previous to Pleistocene is questioned by Shepard and Emery.

Much can be learned from this submerged area as it contains the same structural situations as onshore but with much less deposition and very much less erosion.

MEHRTEN FORMATION EROSIONAL INTERVAL

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During part of the Miocene and Pliocene periods volcanoes covered the bedrock of the northern Sierra Nevada with a mantle of pyroclastic debris, which, in that region, effectively stopped the erosional cycle then in progress throughout the whole Sierra. South of Hetch Hetchy Valley the cycle continued uninterrupted. This cycle was brought to a close by uplift in late or post-Mehrten time; for the surface carved during the succeeding cycle is equally well developed in buried and unburied regions.

Comparison of erosional surfaces and stream-channel cross sections in buried and unburied areas suggests that during the period of volcanism unburied streams evolved from a stage of late youth to a stage of late maturity. The fossil evidence of the Mehrten formation indicates that this development took place between upper Miocene and middle Pliocene time, which, by the current absolute time scale, would be of the order of magnitude of from 5 to 7 million years. The confinement of deposition of the Mehrten formation to a single erosional cycle suggests that volcanism occurred during a period of orogenic quiescence.

PROPOSED GEOMORPHIC EVOLUTION OF CONTINENTAL TERRACES

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Previously, proposals regarding the modification of the continental terrace (*i.e.*, the continental slope and shelf combined) were tied to the concept of wave base and to the belief that much sediment is permanently deposited as foreset beds with steep initial slope angles. These views are discarded. It is proposed that the terrace is modified by surfaction and by currents (especially turbidity currents) that act at all depths. Consequently, sedimentation takes place largely inside the surf zone, as littoral, estuarine, deltaic, and lagoonal deposits, and at the base of the continental slope, as an apron with a low gradient. Other sedimentation on the shelf and on the original continental slope is considered quantitatively unimportant.

Initially the continental slope is considered of structural origin. In youth, surf action cuts the shelf, and an apron of sediments forms at the base of the slope. In maturity, the apron is large, and its weight depresses the underlying crust and also warps down the juxtaposed shelf. This permits preservation of "infra-surf" deposits which have prograded across the shelf. In old age, the apron is built up to cover the entire primary continental slope. Complete rejuvenation can occur by orogeny and partial rejuvenation occurs by epeirogeny. The effects of oscillations of sea level are also considered.

Tentatively, based on terrace profiles obtained from fathograms, the West Coast terrace is believed to be youthful, the Atlantic Coast terrace mature, and the Gulf Coast partially rejuvenated from late maturity. Part of the terrace of Antarctica may be an example of old age.

ORIGIN OF THE SHELF-BREAK

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An abrupt change of slope or "shelf-break" marks the boundary between the continental shelf and the continental slope. The shelf-break has previously been attributed to (1) the formation of a wave-built terrace by sedimentation at wave base in equilibrium with present sea level, (2) formation of a wave-built terrace by sedimentation at wave base but related to some past lowered sea level, (3) wave abrasion in equilibrium with present sea level, or (4) wave abrasion related to some past lowered sea level. To test these various possibilities, the concept of wave base is examined theoretically. Wave base appears unimportant in the regimen of the sea, and it cannot account for the shelf-break. Instead, the break appears to be related to the depth at which breakers form, which is, excluding rare cases, at a maximum depth of about 5 fathoms. The writers term this the "depth of vigorous abrasion." On theoretical grounds, therefore, it appears that shelf-breaks are caused by wave abrasion in the surf zone of formerly relatively lower sea levels. This theory is tested with several field facts which seem to confirm it.

Two implications of this concept are that (1) sea level has recently risen eustatically, and (2) this rise of sea level has taken place very rapidly as compared with change of land elevation caused by sedimentation, erosion, or diastrophism.

BASIN SEDIMENTS OFF SOUTHERN CALIFORNIA

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Each of the dozen basins between the continental slope and the shore line of Southern California is partially filled with sediments. Those nearest shore have the thickest fill, as indicated by their wider and flatter floors and by the coarser median grain size of the fill. The sediments of all except one basin contain some sand layers. Cores through the sediment reveal other significant changes with depth. Chief of these is change in water content, from which it can be shown that compaction, owing to weight of overburden, is limited by resistance to grain deformation rather than by low permeability. The interstitial water that is forced upward by compaction provides a means for selective solution at depth and deposition above, just the opposite of supergene enrichment known on land.

The generally higher pH and lower organic content at depth may lead to solution of silica at depth and deposition of bedded chert nearer the mud surface. Diagenetic changes of significance in the origin of oil are produced by bacteria. These include an increase with depth (and thus with time) of the carbon-nitrogen ratio in the organic matter, and a decrease of both sulfate-chloride ratio and oxidation-reduction potential in the interstitial water. Many of these parameters are controlled by the character of the overlying basin water, which, in turn, is related to the depths of the floor and of the sill of each basin.

FORT SAGE MOUNTAIN, CALIFORNIA, EARTHQUAKE OF DECEMBER 14, 1950

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A series of earthquakes in eastern Lassen County, California, culminated in a strong shock on December 14, 1950. Considerable damage resulted to the Sierra Ordnance Depot at Herlong, and a small loss at Doyle. Fractures opened in the alluvium for a distance of 6 miles at the western base of Fort Sage Mountain. In general these fractures follow an old northerly-trending scarp, the northern 2 miles of which has a height of 50 to 100 feet. On the north the mountain ends in an abrupt scarp overlooking Honey Lake Valley. A scarp also marks the mountain's northeastern side and a less conspicuous scarp terminates it to the south. This gives the mountain a rudely triangular outline with the most acute angle pointing northward.

The recent faults consist mainly of two fractures of about equal length. The southern segment begins 1 mile northeast of Doyle and ends a quarter of a mile north, and 1000 feet west, of the south end of the northern segment. The northern fracture curves around the northern acute angle of the mountain.

About midway another fracture lying a half mile to the west is 2000 feet long. The main fractures have a downthrow to the west with a maximum displacement of 8 inches. The western fracture has a 3-inch downthrow to the east. Aftershocks were felt in late January 1951. There is no lateral displacement.

SUNKEN ISLANDS OF THE MID-PACIFIC MOUNTAINS

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This paper is a preliminary report on part of the material gathered on the 1950 joint U. S. Navy Electronics Laboratory-Scripps Institution Expedition to Bikini. One objective of the expedition was to investigate previously located flat-topped seamounts (guyots of Hess, 1946) in an area west of Hawaii and several hundred miles east and west of 19° N. Latitude and 173° W. Longitude.

Echo-fathometer surveying revealed that the guyots are peaks on a chain of mountains from the Hawaiian Islands to the vicinity of Wake Island. This submarine mountain range is to be named the Mid-Pacific Mountains. Echo-fathometer surveying, dredging, and coring on the guyots revealed:

(1) Flat tops at depths between 700 and 900 fathoms with side slopes near the top around 20°
(2) Rounded, basaltic pebbles, cobbles, and boulders
(3) Sandstone of basaltic source
(4) Limestone resembling beach limestone formed on modern atolls
(5) A fossil fauna including several genera of reef corals, rudistids, stromatoporoids, pelecypods, gastropods, and an echinoid. Preliminary study indicates a Middle Cretaceous age.
(6) Scattered banks above the break in slope which resemble coral banks on flat platforms

Conclusions are that an ancient chain of basaltic islands was located in the area investigated; that these islands were eroded to platforms on which lived a warm, shallow-water fauna; that rapid subsidence killed the reef coral; and that this subsidence occurred near the Middle of the Cretaceous period.

REVISION OF DEVONIAN AND CARBONIFEROUS SECTIONS, NOPAH RANGE, INYO COUNTY, CALIFORNIA

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Restudy of the Devonian and Carboniferous beds exposed in the northern part of the Nopah Range shows that some revision is necessary. The section above the unconformity at the base of the Devonian was originally divided as follows:

Middle Devonian, Sultan dolomite, 890 feet; Mississippian, Stewart Valley limestone, 1180 feet and Monte Cristo limestone, 987 + feet; Pennsylvanian, Bird Springs formation (?), 780 + feet.

The following revision is offered. The name "Stewart Valley limestone" is dropped, and the section divided as follows:

		Feet
Middle Pennsylvanian (Des Moines Series)		
Bird Springs formation		995+
—— Unconformity(?) ——		
Lower Pennsylvanian (Lampasas? Series)		100+
—— Missing interval in section ——		
	estimated 400–500 feet based on regional information	
Lower Mississippian (Osage Series)		
Monte Cristo limestone		1587+
Yellow Pine(?) limestone	100+	
Bullion limestone	515	
Anchor limestone	622	
Dawn limestone	350	
—— Unconformity ——		
Middle Devonian		
Sultan limestone		1720
Crystal Pass limestone	140	
Valentine limestone	1240	
Ironside dolomite	110	
Basal member	230	
—— Unconformity ——		
Middle Silurian dolomite		335

All formation names are those used in the Goodsprings district, Nevada, 45 miles to the southeast.

This revision is based upon new faunal collections and recognition of an unconformity at the base of the Lower Mississippian. Faunas from the beds here designated uppermost Mississippian or basal Lower Pennsylvanian, a unit not heretofore recognized, are poorly preserved, and the section is largely covered. Lithologically this unit is similar to the Indian Springs member of the Bird Springs formation, described by Longwell and Dunbar in the Spring Mountains, ± 40 miles northwest of Las Vegas. Excellent faunas show the Indian Springs beds to be of Upper Mississippian (Chester) age. No Permian elements are present in the beds here referred to the Bird Springs formation.

USE OF GEOPHYSICAL METHODS IN THE SEARCH FOR REEFS

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A generalized cross section on the eastern platform of the Permian Basin shows the complexities of the problems involving reef conditions. Because of these complexities, the success or failure of geophysical methods has varied so widely in the solution of the reef problem that individual successes have been attributed as much to the experience and interpretative ability of an individual geophysicist as to a particular method.

Evidence is presented to show that, in general, most of the geophysical successes are attributed to the seismic method. However, gravity and aeromagnetic data are shown to illustrate their usefulness as, at least, reconnaissance methods to "High Grade" provinces where reefing is known. By concentrating the seismic work first in "High Grade" areas, time is saved in carrying out a successful program in the search for reefs. Today, the companies having the lowest risk ratios are using all three methods to solve the reef problem.

STRATAL RELATIONSHIPS OF THE SUPAI FORMATION OF CENTRAL ARIZONA

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An investigation of the stratal relationships of the Supai formation was conducted in central Arizona in the summer of 1950. The area studied includes Sycamore Canyon on the northwest; Oak Creek, Munds, and Beaver Creek canyons to the southwest; and the Mogollon Rim from Pine eastward to Promontory Butte. The Mogollon Rim and many colorful canyons of northern Arizona are carved into the Supai formation.

To understand the stratigraphic relationships of the Supai formation better, a series of eight detailed sections was measured. Correlation and comparison of the writer's Fossil Creek section with the Oak Creek section of McKee to the West, and the composite section of Winters at Fort Apache to the east is made through faunal and facial relationships.

The Supai formation in eastern and central Arizona is divisible into units through lithology and topographic expression. The lower units of the Supai formation intertongue with the Naco formation (Pennsylvanian) to the east. The upper limestone facies of the Naco formation crosses time lines, ascending in the geologic column eastward. The upper limestone facies of the Naco formation at Fossil Creek contains a fauna of Des Moines age. The upper limestone facies of the Naco formation at Fort Apache contains a fauna of Missourian and Virgilian age.

The Supai formation of central Arizona is an advancing continental deltaic deposit of Pennsylvanian-Permian age which has caused regression of the Pennsylvanian sea due to sedimentation exceeding subsidence on a stable to mildly unstable depositional shelf.

VASQUEZ SERIES IN THE UPPER TICK CANYON AREA, LOS ANGELES COUNTY, CALIFORNIA

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The stratigraphic and structural relations of rocks exposed in the Tick Canyon-Vasquez Rocks area of Los Angeles County may have useful application elsewhere in the Ventura Basin and adjacent parts of southern California. In this small area, pre-Cretaceous crystalline rocks are faulted against a tilted and locally folded nonmarine section of sedimentary and volcanic rocks that represent parts of the Vasquez series and the Tick Canyon and Mint Canyon formations, all of Tertiary age.

The Vasquez beds comprise siltstone, sandstone, and conglomerate, with subordinate breccia, limestone, tuff, and borate-bearing layers. They are nearly 3000 feet thick and are intertongued with 2300 feet of basaltic flows and breccias. All these rocks are stratigraphically high in the Vasquez series and are unconformably overlain by the Tick Canyon formation, which includes siltstone, sandstone, conglomerate, and local basalt-rich basal breccias of talus and debris-flow origin. Vertebrate remains of late Lower Miocene or earliest Middle Miocene age occur at two horizons in the Tick Canyon section, but the underlying strata have yielded no diagnostic fossils.

The rocks of the Vasquez series are much more closely folded here than in areas to the east and southeast, and are overlain with pronounced angular discordance by the Tick Canyon beds. Moreover, northeast-trending faults that cut the Vasquez rocks show little displacement in the younger formations. Both the borate-bearing beds and the volcanic rocks in the Vasquez section evidently are older than most rocks of similar lithology elsewhere in southern California.

CRETACEOUS DEPOSITS OF THE PUNTA SAN ISIDRO AREA, BAJA CALIFORNIA

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Recent investigations on the west coast of Baja, California between San Antonio del Mar and Ensenada have yielded data amplifying previous interpretations of the Cretaceous formations of this region and their relationships.

The Cretaceous sequence in this area lends itself to a two-fold division. The lower part of the section, dominantly volcanic rocks with interbedded limestones, is referred to the Alisitos formation of Santillan and Barrera. It contains an unusual fauna of coral-echinoid-rudistid elements comparable to the Middle Cretaceous assemblages of southern Mexico and Texas. The rudistids are considered conspecific with those described by Palmer from the Cenomanian deposits of the State of Jalisco. The Upper Cretaceous (Maestrichtian) deposits are dominantly sandstones and are referred to the Rosario formation of Santillan and Barrera. In this area the Rosario formation, with a heavy conglomerate at its base, rests with marked unconformity on the Alisitos formation.

The fauna of the Rosario formation is closely related to that of the Maestrichtian deposits of California, but the fauna of the Alisitos formation has nothing in common with known California faunas of similar age.

OGIVES OF THE EAST TWIN GLACIER, ALASKA—THEIR NATURE AND ORIGIN

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The excellent development, fine exposure, and unusual accessibility of ogives on East Twin Glacier, Alaska, makes this an exceptional place in which to study the nature and origin of this phenomenon.

The origin of ogives is discussed, and previous hypotheses are critically analyzed. With the exception of a hypothesis first suggested by R. T. Chamberlin—that ogives are the surficial expressions of shearing planes—no other hypothesis satisfactorily accounts for the fact that these ogives are exposed edges of layers of denser and dirtier ice than the intervening layers. Concepts of glacier flow evolved by Demorest provide a reasonable mechanism for understanding their formation—namely, periodic obstructed extrusion flow downglacier from an icefall. Debris originally basal is believed to become, by upthrusting and ablation, the surface manifestation of an ogive.

ORIGIN OF BORON IN THE GROUND WATERS OF CALIFORNIA

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Boron in irrigation waters in amounts greater than, say, one part per million, has a detrimental effect upon agriculture; this limiting value is exceeded in the ground water of several areas in California under study by the U. S. Bureau of Reclamation. The chemical properties and geographical occurrences of natural waters are reviewed and compared with high-boron ground waters, and it is demonstrated that most of the latter indicate the presence of boron-rich solution similar to those found in many hot springs. It is concluded that "normal" ground water may be contaminated by juvenile water arising along fault planes or similar channels.

UPPER ORDOVICIAN, SILURIAN, AND DEVONIAN STRATIGRAPHY OF THE TINTIC MOUNTAINS, UTAH*

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Several accurately located faunal zones in the Paleozoic rocks of the Tintic Mountains, Utah yielded fossils that have been dated by members of the Paleontology and Stratigraphy Branch of the United States Geological Survey† as Upper Ordovician, Middle Silurian, and Upper Devonian;

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† Jean Berdan, Josiah Bridge, P. E. Cloud, Jr., Helen Duncan, and J. S. Williams.

the stratigraphy of this part of the section must be drastically revised. An important part of the Ordovician to Mississippian rocks in the Tintic district as previously described includes:

1. Bluebell dolomite, 800 feet thick, Lower to Upper Ordovician.
2. Pinyon Peak limestone, 150 feet thick, Upper Devonian.
3. Victoria quartzite, 100 to 200 feet thick, Lower Mississippian.
4. Gardner dolomite, 750 feet thick, Lower Mississippian.

Faunas found in this part of the section have led to the following revisions:

1. No Lower Ordovician is present in the Bluebell dolomite; the entire cherty lower unit is Upper Ordovician, known locally as the "Eagle dolomite", and is about 200 feet thick on Pinyon Peak. The upper 600 feet of the Bluebell is assigned to the Silurian because of distinctive Silurian pentamerid brachiopods and corals in the beds above the "Eagle dolomite." This is the first discovery of an undoubted Silurian fauna in this part of Utah.

The stratigraphic location of the Upper Devonian Pinyon Peak limestone was incorrectly designated in the original description (Professional Paper 107) as between the Bluebell dolomite and the Victoria quartzite. It lies between the Victoria quartzite and the Gardner dolomite and comprises the lower beds of what has been called Gardner dolomite. The lithology of the uppermost beds of the Bluebell is strikingly similar to that of the "eye" bed in the Devonian Jefferson formation of the Ophir district and may be of the same age. The "eye" bed is included in the restricted Bluebell dolomite; the Victoria quartzite is assigned to the Devonian, however, and the strongly channeled contact on which the lower sandstone rests is taken provisionally as the base of the Devonian in the Tintic Mountains. Only two inconclusive fossils were found in the Victoria quartzite.

The Pinyon Peak limestone, as redefined, comprises the beds formerly included in the three lower units of the Gardner dolomite, now known to contain an Upper Devonian fauna. It is at least in part correlative with the Three Forks shale. The beds are known locally as the "Mottled dolomite" (72 feet thick), the "Blue flaky limestone" (120 feet thick), and the "White limestone" (30 feet thick); total thickness 222 feet. The restricted Gardner dolomite is about 535 feet thick and contains lower Mississippian fossils in its basal bed. It is correlated with the Madison limestone.

ANALYSES OF FOSSIL REEF-TYPE FACIES

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Fossiliferous, massive facies lenticles occur scattered through the bedded sedimentary deposits of all ages. Generally referred to as organic reefs, they actually comprise a heterogeneous aggregate of genetically unrelated ecologic entities. Progress in differentiating these categories to reach a clear understanding of the evolutionary aspects of true reefs through geologic times requires strict application of a consistent reef concept. Reefs are here defined in terms of ecologic potentials of reef-building organisms, capable of erecting rigid, wave-resistant structures. This constitutes the basis of the following analyses of fossil reef-type facies.

The Niagaran structures of the Interior of North America have recently been shown to constitute true reefs in conformity with this definition. Their basic reef aspects are briefly reviewed. Emphasis is placed on the dynamics of reef growth. Factors affecting reef development, insofar as recognizable, such as circulation depth and conditions of sedimentation, will be discussed.

The basic aspects of the Niagaran reefs will be compared with a number of "reefs" recently examined in Europe, North Africa, and Japan, ranging in age from Cambrian to the Pleistocene. The "reef" occurrences discussed fall into three categories: (1) potentially true reefs, of which, however, only initial quiet to semirough water stages were observed, (2) consolidated and unconsolidated banks, and (3) dense, localized carpet successions of sessile benthos which lacked the potential to raise their own substrate. No true wave-resistant reef stages were encountered in any of the foreign occurrences.

GROUND-WATER CONTAMINATION BY SALINE THERMAL WATERS

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A chain of large oil refineries, northwest of Salt Lake City, is rapidly increasing demands on ground water for industrial use. The refineries are near the base of a bold, westward-jutting mountain spur

that is bordered by a flat abandoned lake plain. The junction of the plain and mountain front is abrupt and marks the position of a fault zone along which highly mineralized thermal waters rise and issue at various places along its course as hot salt springs.

Ground water in the area occurs in small alluvial fans built westward from the mountain front in former "interlake" intervals, but now buried by relatively impervious lake silts and clays. Artesian water occurs at depths varying from 70 to 600 feet. Well logs indicate extreme irregularity of the aquifers in both shape and thickness; lenslike and wedgeshapes predominate, making correlation unreliable even between neighboring wells.

Some aquifers contain fresh waters with dissolved solids from 500 to 1000 parts per million; others contain highly mineralized salt water with as many as 15,000 parts per million, of which 8000 parts is chlorine. These saline waters are identical with those associated with the fault zone; and they have been encountered in wells more than a mile from the fault.

Increased draft on ground water in recent years is permitting encroachment and contamination by the hot salt water; certain wells show as much as 60 per cent increase in chloride in just the past 3 years.

DYNAMIC ROLE OF DILATANCY IN THE MIGRATION AND ACCUMULATION OF OIL IN METAMORPHIC ROCKS: A HYPOTHESIS*

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The difficulties inherent to the prediction of potential reservoir conditions in basement rocks buried by a concealing mantle of sediments are apparent to all geologists and constitute the main cause for prejudice against basement exploration. Consequently geologists have not played an important role in the discovery of oil accumulations in basement rocks. All the major discoveries have been accidental.

Our record can be improved by a critical examination of our working hypotheses concerning the nature of the geological processes responsible for the formation of basement oil pools. Among these hypotheses is the generally accepted "Up Slope" theory of oil migration in basement reservoirs. The theory is closely patterned after our working concept of migration of oil in conventional sandstone carrier beds. The theory and its limitations as a guide for exploratory work are discussed.

An alternative proposition is advanced that fracturing of competent basement rocks involves dilatancy which in turn reduces hydrostatic pressures in focal areas of deformation. Pressure gradients are thereby established between the potential basement reservoir rocks and the overlying source and carrier beds containing oil, gas, and water. Thus a tendency to "suck in" fluids into the basement rocks is established. The hypothesis appears to be compatible with the field evidence in several basement oil pools in southern California.

MENDOCINO SUBMARINE ESCARPMENT

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A submarine scarp extends westward from Cape Mendocino, California, for at least 1000 miles. The height 70 miles from shore is about 10,500 feet, and 1000 miles from shore it is about 6100 feet. The maximum average slope from top to bottom varies between 7° and 10°; but portions of the scarp 1000 feet high have slopes as great as 18°–24°. The scarp lies on the south side of a ridge which has a much gentler northern slope. Similar, but smaller, ridges and scarps are found north and south of the Mendocino Scarp and parallel it. Regional bathymetry shows that the sea floor for hundreds of miles south of the scarp is about half a mile deeper than the sea floor for hundreds of miles north of the scarp.

The San Andreas fault appears to trend northwest from Cape Mendocino rather than bending west to follow the Mendocino Scarp. The scarp may mark a strike-slip fault, a "continental slope", or the north side of a vast graben.

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SILURIAN QUARTZITES OF THE INYO MOUNTAINS, CALIFORNIA*

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In the southern Inyo Mountains, California, the upper part of the Silurian dolomite section includes quartzite locally more than 300 feet thick. Two quartzite units are recognizable: (1) a lower unit inclined to be dense, vitreous, and heavily bedded; and (2) an upper unit that is thinner-bedded and interbedded with abundant dolomite. The upper unit on the east side of the Inyo Mountains at the Bonham talc mines contains a large silicified fauna of probable late Niagaran age, including *Halysites*, *Pentamerus*, and atrypas. Silurian quartzite throughout the southern part of the Inyo Mountains appears to be an exceptionally favorable host for talc, especially in thce zone of alternatin dolomite and quartzite beds. On the west side of the range the upper quartziti unit passes throughg interbedded quartzitic dolomite and marble into the Devonian marble sequence. It is believed that the Silurian quartzites are very lenticular and may pinch out a few miles to the east and northwest in the Inyo Mountains. Attention is called to existence of similar quartzites or quartzitic sands of Ordovician through Devonian age in the Inyo Mountains: sand in the upper part of the Pogonip limestone, Eureka quartzite, upper Silurian quartzite, Middle Devonian quartzite. The Devonian quartzites are thin, generally less than 30 feet, but lithologically they resemble both Eureka quartzite (Ordovician) and the Silurian quartzites. The heavy lower division of the Silurian quartzite may quite easily be confused with the Eureka, especially in deformed sections.

GEOLOGY OF THE SANTA YSABEL QUADRANGLE, CALIFORNIA

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More than half the Santa Ysabel quadrangle consists of pre-Southern California batholith, Paleozoic(?) schists, granitic intrusives, and mixtures of these rocks. This complex was intruded by a series of Cretaceous batholithic rocks ranging from gabbro to tonalite.

In the north and northeast portions of the area late Tertiary (?) and Quaternary alluvial and lacustrine(?) sediments have accumulated in basins produced by normal faulting. Faulting has continued to the present and is largely responsible for the existing topography.

LARGE THRUSTS IN NORTHERN CASCADES OF WASHINGTON

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East of the upper Skagit in the northernmost High Cascades, the Jack Mtn.-Mt. Hozameen Range consists of (?) Permian greenstones with cherts thrust over Lower Cretaceous clastic sediments which are strongly folded and on the west dynamically metamorphosed. Small serpentine intrusions occur near the contact. The thrust mass has been folded into a huge north-northwest trending syncline. Erosion has exposed the Cretaceous substratum in both synclinal limbs and around the plunging southern nose of the syncline where later uplift has been caused by an intrusion farther south representing the latest phase in a series of granitic evolution beginning with metasomatism. Thrusting has been to the east-northeast. The root is obscured by regional granitization on the west, but the extent of thrusting is at least 10 and possibly 25 miles.

Another large thrust was found about 60 miles east of this area. East of the Okanogan Range (northeasternmost Cascades) in the Riverside-Conconully region, Devonian (?Mississippian) dolomites succeeded by Carboniferous-Permian clastic and volcanic rocks (Anarchist) form a regional thrust plate overlying Anarchist rocks exposed in several anticlinal windows. The upper plate exhibits metamorphism of various grades including some granitization, intense folding, and minor thrusting, the trends averaging northwest. Most of this folding and metamorphism antedate the main thrust. The exposed parts of the lower plate exhibit intense mechanical metamorphism. Imbricate mylonites and serpentine sills surround the windows. Subsequent folding has deformed the thrust

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plane. Folding and thrusting have been to the northeast. On the east these structures are truncated by a later fault along the Okanogan valley. Thus the extent of thrusting remains undetermined, but it probably greatly exceeds the 8 miles visible within the area surveyed.

EVIDENCE OF A MAJOR FAULT TRUNCATING THE EASTERN END OF THE SANTA MONICA MOUNTAINS, CALIFORNIA

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The structural and topographic expression of the Santa Monica Mountains ends abruptly along a nearly north-south line parallel to the Los Angeles River. The distribution of the basement rocks (pre-Cretaceous) gives reason to explain this truncation by a left-lateral, strike-slip fault of 6–7 miles displacement. The basement rocks around Forest Lawn, east of the fault, are the same as those in the Santa Monica Mountains west of Cahuenga Pass. The Santa Monica Mountains east of Cahuenga Pass comprise a geologically discordant block, having different basement rocks, and separated on the west side from the rest of the mountains by a major fault. This block interrupts the continuity of the Santa Monica Mountains' basement into the area around Forest Lawn, and it seems likely that the proposed fault forms the eastern boundary of this block. The major movement along the inferred fault appears to be pre-Upper Miocene.

West of Cahuenga Pass, foliated quartz diorite intrudes the Santa Monica formation. The regional attitude of the foliation in the igneous and metamorphic rocks is consistently N. 65° W., 60–70° N.E. The igneous-metamorphic contact is present east of the Los Angeles River, but 6–7 miles north of where it should occur if projected from its exposures in the Santa Monica Mountains. A zone of microbreccia in the northern part of the quartz diorite intrusive parallels the foliation, and is also offset 6–7 miles northward on the east side of the Los Angeles River.

SAN GABRIEL AND RELATED FAULTS IN THE WESTERN SAN GABRIEL MOUNTAINS, CALIFORNIA

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The San Gabriel fault is a San Andreas-type rift extending west-northwesterly for about 70 miles from a point near Pasadena obliquely across the east-west San Gabriel Mountains to a probable junction with the San Andreas and Garlock-Big Pine faults in the Tehachapi Mountains west of Lebec.

Geologic mapping (1:24,000) in an area several miles wide on both sides of the San Gabriel fault in the western San Gabriel Mountains shows that that fault zone and related faults comprise (1) a principal series of steep north-dipping shear planes, along the San Gabriel fault proper, trending N. 65° W. and showing right lateral movement; (2) in the north block, a series of subordinate left lateral Garlock-type faults trending predominantly N. 65° E.; and (3) in the south block, a group of reverse faults.

An ancestral San Gabriel fault, with south block topographically high, was present as early as Mint Canyon (upper Miocene) time as is shown by over 4000 feet of continental Mint Canyon sediments on the north side against older crystalline rocks on the south side. Displacements of marine Pliocene and continental lower Pleistocene formations, and offset of major stream courses give evidence for post-Pliocene right lateral movement of 2.7 miles along the fault, at least 1.5 miles of which is probably post-lower Pleistocene. Seven of the north-block left lateral faults show offsets of formational contacts and structural features ranging from 0.4 to 2.2 miles. The south-block reverse faults show essentially dip-slip movements from several hundred to over 2000 feet; some are cut by the slightly younger San Gabriel fault.

Results of late-Tertiary–Quaternary faulting and folding in the western San Gabriel Mountains are consistent with development of a stress-strain system involving crustal shortening in a north-south direction combined with action of a force couple along the San Gabriel fault.

WILDCAT GROUP IN THE EEL RIVER AREA, HUMBOLDT COUNTY, CALIFORNIA

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The Wildcat Group (originally Wildcat Series of Lawson) is composed of predominantly clastic sediments of upper Cenozoic age. The maximum thickness, over 12,000 feet, is exposed in the vicinity of Eel River and Price Creek. In the Ferndale Hills, on the south side of the basin, the Wildcat Group can be subdivided into five formational units. The lower three units each have a characteristic foraminiferal fauna. The ages of these formations range from upper Miocene (Mohnian) to possibly lower Pleistocene. Northeast of Fortuna these formations cannot be differentiated. Thinning of formational units, facies variations (characteristic of a limited basin), minor unconformities, and overlap result in rapid changes of thickness and character of sediments. For example, from the maximum of 12,000 feet of complete section at Eel River, the Wildcat thins to the northeast to less than 500 feet of upper Pliocene sediments unconformably overlying sediments of questionable upper Jurassic to lower Cretaceous age. Sedimentary features and fauna indicate: (1) a transgression of the upper Miocene sea, (2) minor fluctuations during the Pliocene, and (3) regression in upper Pliocene followed by the deposition of coarse continental clastics in the lower Pleistocene.

Folds have a general east-west strike and include the major Eel River syncline and smaller anticlines to the south and north. East of Fortuna these structures are cut by the northwest-striking Yager and Little Salmon faults.

EVIDENCE OF INSTABILITY OF PACIFIC BASIN

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Recent geophysical and geological investigations of the floor of the deep Pacific indicate that this area has been the scene of large-scale geologic activity during relatively late stages of earth history. Both seismic and paleontologic evidence suggests that Bikini Atoll began to form on a volcanic base in Mesozoic or Early Tertiary time. Shallow-water fossils from dredgings on the Mid-Pacific Mountains show that the tops of the seamounts which form the summit of this range, now at depths of 2500 to 6000 feet, were near the sea surface during Early Tertiary or late Cretaceous time. The lower slopes of many deep topographic highs rising above the level of the sea floor appear to consist of talus unburied by sediment. Volcanic ash layers in cores from different areas indicate local submarine volcanism during the Pleistocene. Finally, the apparently slight thickness of deep-sea sediment suggests that relatively rapid deposition did not begin until the Mesozoic.

CRYSTAL-FABRIC STUDIES ON THE EMMONS GLACIER, MOUNT RAINIER, WASHINGTON

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Optical orientations of 1725 ice crystals were determined at 11 locations on the Emmons Glacier by means of a 6-inch universal stage mounted between crossed polaroid sheets. The crystals were 0.2 to 6 inches across, and from 3 to 40 were included in each 4½- by 6-inch thin section. Downvalley glacier movements of 3 to 9 inches per day were recorded at four of the higher locations, and another three were in ice believed to be essentially stagnant.

The optic axes at each location, when plotted on a Schmidt equal-area projection, form consistent patterns featuring four strong maxima, with concentrations as high as 26 per cent per 1 per cent area, at the corners of diamond-shaped quadrangles. The angular separation of opposite corners of these diamonds average 84° and 52° respectively. The pattern in stagnant ice is the same and as strong as the pattern in moving ice. Poles to shear planes and blue ice bands in the ice at the locations studied fall near the centers of the diamond-shaped quadrangles. If this pattern is controlled by gliding within the ice crystals, it suggests the possibility of glide planes in ice crystals other than the well-known basal glide plane.

SUBDIVISION OF VERTEBRATE-BEARING NONMARINE PLIOCENE ROCKS IN WEST-CENTRAL CONTRA COSTA COUNTY, CALIFORNIA

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Field studies of the geology and paleontology of west-central Contra Costa County indicate need for a clarification and revision of stratigraphic terms. A new group name is proposed to include the following rocks:

(1) Orinda formation (Mio-Pliocene flood-plain deposits)
(2) Moraga formation (Lower Pliocene volcanics and interbedded nonmarine sediments)
(3) Siesta formation (Lower Pliocene lake beds)
(4) Bald Peak formation (Lower to Middle? Pliocene volcanics and lacustrine sediments)
(5) A new formation (Middle Pliocene flood-plain and lacustrine sediments with minor tuffs)

Unit (5) was originally mapped as Orinda; but a separate formational name is warranted so that the structural and stratigraphic relationships of the rocks of this area may be properly demonstrated. The new formation has not presently been mapped in direct superposition to the other formations but is exposed east of the Moraga fault system in fault contact with the Siesta and Moraga formations.

Assemblages of fossil vertebrates, collected in the type areas of these formations, have furnished unusual opportunity to determine stratigraphic relationships. Comparison of these assemblages with all known Pliocene mammalian faunas indicates:

(1) *Nannippus tehonensis* (horse), from the Orinda, existed only in early Clarendonian time (very early Pliocene)
(2) *Eucastor leconlei* (beaver) and *Hipparion* cf. *mohavense* (horse), from the Siesta, are restricted to later Clarendonian time
(3) *Teleoceras* cf. *fossiger* (rhinoceros), *Dipoides* (beaver), and *Pliohippus* cf. *spectans* (horse) found in the new formation, existed only in Hemphillian time (Middle Pliocene).

LANDSLIDE CAUSED BY OVER-IRRIGATION NEAR CAMBRIDGE, WASHINGTON COUNTY, IDAHO

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In June 1949 a landslide developed on the N. D. Dixon ranch 21 miles west of Cambridge, Idaho. About 200 yards east of the ranch house is a 300-foot terrace scarp. A portion of this terrace, called the upper ranch, was irrigated after a lapse of 12 years. East of the terrace are Paleozoic sedimentary rocks overlain by horizontal Tertiary(?) lavas. Pleistocene gravels fill a large valley in these beds and cover most of the uneroded lavas. Eighty acres of the 140 acre terrace was sliding, threatening the lower ranch and house. Many small landslides scar neighboring terraces, but none is as large as that described.

Apparently the large amount of water (300 to 400 miners inches) applied to the land that spring, and moisture from the record snowfall of the previous winter lubricated the gravel-lava contact. Fractures developed at the head and both sides of a 12 million cubic yard slide, and a few small bulges formed at its front. Two parallel fissures, about a quarter of a mile long and about 50 feet apart, developed at its head. The fissures are 3 or 4 feet wide and 10 to 20 feet deep; the land between them drops as much as 15 feet. Fences were moved as much as 8 feet out of line.

The slide evidently results from over-irrigation and unfavorable geological conditions. The near-disastrous results indicate that both proper geological conditions and a water supply are needed for a successful irrigation project.

It was recommended that irrigation be discontinued that season and also in the future or the house should be abandoned.

ACCUMULATION AND ABLATION ON THE SEWARD-MALASPINA GLACIER SYSTEM, CANADA–ALASKA

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Upper Seward Glacier, an intermontane ice body, is the principal source of nourishment for Malaspina Glacier, a piedmont sheet on the southern Alaska coastal plain. The state of health and degree of actvityl of this system, covering 1650 square miles and involving about 420 cubic miles of ice, are besti evauated through records of accumulation and wastage.

Annual surplus in the accumulation area was 69 inches of water in budget year 1948–1949, 26 inches in 1947–1948, 17 inches in 1946–1947, and 30 inches in 1945–1946. A preliminary estimate for 1949–1950 is 30 inches, which is thought to be about normal under present conditions.

Daily gross ablation of firn in mid-summer on upper Seward Glacier ranged from a mean of 0.30 inch of water to a maximum of 0.87 inch. Ablation on the upper Seward in the summer of 1948 was 75 per cent greater than in 1949 over a corresponding period of 32 days. Daily gross ablation on clean Malaspina ice averaged 2.32 inches of water in 1949 or nearly nine times the rate on upper Seward Glacier.

As to material balance, 1948–1949 yielded a surplus of 9.01×10^{13} cubic inches of water owing to heavy accumulation and reduced ablation. Budget year 1947–1948 produced a deficit of 2.144×10^{14} cubic inches, more than counterbalancing the surplus of 1948–1949. Under existing climatological conditions even a normal year produces a deficit of about 2×10^{14} cubic inches. This glacier system is obviously in a poor state of health.

COMPOSITE ORIGIN OF SUBMARINE CANYONS

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Much of the recent exploration of the sea floor has contributed toward the solution of the problems raised by submarine canyons. A hypothesis which appears to be in agreement with all the recent discoveries is as follows:

(1) The deeply incised rock-walled canyons were cut at various times, mostly before the Pleistocene, as the result of occasional reversals of major downward movements of the continental margins.
(2) Deltas were formed at the mouths of these canyons.
(3) The canyons have reached their present positions as the result of the major downward movement so clearly demonstrated from the great thicknesses of shallow marine and terrestrial deposits found in wells drilled along the coasts of continents and in oceanic islands.
(4) During the submergence, submarine landslides, such as are known to occur at the near-shore heads of canyons along the California coast, have kept the canyons open.
(5) Subsequent to submergence the deltas have gradually undergone slump which has opened up large frontal cracks, down which turbidity currents have moved, transforming them into valleylike features. These relatively shallow valleys with natural levees on the side extend to the base of the slopes giving a false notion of great submergence for the canyons.
(6) The fresh appearance of the inner gorges seen by diving into the canyon heads is the result of subaerial erosion during the last glacial stages.

The hypothesis appears to answer all the objections raised in recent years to the subaerial origin of the canyons and does not necessitate the calling upon turbidity currents for which there is no existing evidence of a capabiiity to produce erosion particularly through hard rocks such as granite.

BRECCIA PIPES OF THE TERLINGUA DISTRICT, TEXAS*

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The numerous breccia pipes of the Terlingua quicksilver mining district of western Texas are circular or oval in plan and have near-vertical borders. They are found in shale, sandstone, and

* Publication authorized by the Director, U. S. Geological Survey.

limestone of Cretaceous age. The breccia is composed of these rocks together with Tertiary volcanic rocks. In a few of the pipes the breccia has been invaded by Tertiary hypabyssal intrusions ranging in composition from basalt to rhyolite.

In all pipes the breccia has been displaced downward relative to the surrounding rocks. Apparently therefore, the pipes originated by solution of limestone and gravitational subsidence of the overlying rocks. Subsidence began by slabbing from the roofs of caverns that had become too broad to be structurally sound. Once formed, the cylindrical masses of breccia continued to move downward and enlarge upward as long as space was provided below by continued solution of limestone. In some pipes only 250 feet in diameter rocks are found that were originally more than 2000 feet stratigraphically above the limestone. Many limestone caverns that are small enough to be structurally sound are still open today. Approximate contemporaneity of the pipes with igneous and hydrothermal activity in the area suggests that the limestone was dissolved by volcanically heated and mineralized water rather than by ordinary ground water.

LARAMIDE STRUCTURES IN THE PAROWAN GAP AREA, SOUTHWESTERN UTAH, AND THEIR RELATION TO THE COLORADO PLATEAU-BASIN AND RANGE BOUNDARY

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Excellent exposures in and around Parowan Gap, in a minor fault block a few miles west of the Hurricane Cliffs in southwestern Utah, show Jurassic and Cretaceous strata overturned and thrust eastward over flat-lying Upper Cretaceous. The structure is truncated and overlain unconformably by essentially flat-lying "Pink Cliffs Wasatch," with a thick boulder conglomerate at its base.

Inasmuch as the youngest beds beneath the unconformity overlie strata which contain a Coloradoan marine fauna, they are probably of late Coloradoan or Montanan age. The lower half of the "Pink Cliffs Wasatch" conglomerate immediately above the unconformity closely resembles conglomeratic phases of the Kaiparowits formation (late Cretaceous) of the western margin of the Markagunt Plateau a few miles to the east. The Parowan Gap structure is thus dated approximately as late Cretaceous (late Montanan?), and it is essentially contemporaneous with similar overturned anticlinal or monoclinal structures recently described by Gregory along the Hurricane fault zone immediately to the south, near Cedar City and Kanarraville, and by Mackin in the adjacent Iron Springs District to the Southwest.

Areas in which these structures are found lie along or west of the Hurricane Cliffs and are generally regarded, physiographically, as part of the Basin and Range province. The structures, however, are individual welts in otherwise little-disturbed strata of distinct Colorado Plateau aspect and are, therefore, more nearly comparable to Laramide flexures in the Plateaus than to large-scale folds and thrusts in the Basin and Range province. Thus these areas along the Plateau-Basin and Range boundary are of mixed character, geologically. Alternative interpretations of their affinities are offered.

FOUNDATION PROBLEMS, FOLSOM DAM PROJECT, CALIFORNIA*

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The Folsom Dam Project, on the American River near the Folsom Prison, is under construction by the Corps of Engineers. The abutments of the concrete gravity river section have been partially excavated in deeply and irregularly weathered quartz diorite and at present are being taken to foundation grade. Effects of weathering appear to be structurally controlled, principally by a joint set generally striking N. 45° E., across the dam axis (S. 60° E.) and dipping 45° NW. Joint surfaces may be coated with slickensided chlorite and sericite, but no displacement has been observed, and apparently the amount of movement is small. Zones of hydrothermal alteration, from 0.1 to 0.5 feet wide, are associated with this set. A second set of joints, striking N. 88° E., and dipping 75° SE., is parallel to a faint gneissoid structure and in some instances is sufficiently persistent to permit orientation of diamond-drill core. Weathering is not so intense as it is along the first set. Several

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narrow, discontinuous faults, of minor importance, are roughly parallel to this set and show as much as 6 inches horizontal displacement. Weathering along other joint sets has separated hard, fresh quartz diorite into huge blocks which are surrounded by varying thicknesses of decomposed diorite. Diamond- and percussion-drill exploration indicates that foundation rock will be reached at or above a line proposed in pre-construction reports.

CROSS-LAMINATION IN THE SALT WASH SANDSTONE MEMBER OF THE MORRISON FORMATION*

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The Salt Wash sandstone member is an interbedded sequence of mudstone and cross-laminated sandstone deposited in a fluviatile environment. Bedding in the Salt Wash sandstone consists mainly of compound low-angle cross-lamination and of festoon cross-lamination. Other common sedimentary structures include current lineation, ripple marks, and slump structures.

Studies of cross-laminae orientations were made at 55 localities. The data were analyzed statistically, using a modification of the methods outlined by previous authors. The resultant dip azimuths of cross-laminae indicate that the streams depositing the Salt Wash sandstone member flowed north, east, and southeast from south-central Utah, and the main source of the Salt Wash lay to the south in southwestern Arizona.

PRE-CRETACEOUS STRATIGRAPHY OF THE NORTHERN KLAMATH MOUNTAINS

Francis G. Wells, George W. Walker and J. M. McIntyre†

Most of the rocks assigned to the Precambrian by earlier workers are now known to be metamorphosed Mesozoic rocks; others are pre-Silurian though not necessarily Precambrian.

Unnamed sediments east of Scott Valley that were formerly considered to be Devonian are now known to be Silurian and will be given a formational name. Small patches of Devonian limestone in undetermined stratigraphic relations crop out nearby.

The Applegate group of metavolcanic rocks with some metasediments underlies the northeastern part of the region. They were formerly thought to be of Devonian or Carboniferous age but Wells has assigned them to the Upper Triassic.

Taliaferro's correlation of the Dothan formation as Oxfordian and therefore below the Galice formation of Kimmeridgian age is verified.

Knoxville sediments, as mapped by Diller, and parts of the Myrtle formation that contain Knoxville fossils are assigned to the Tithonian. Knoxville rocks rest unconformably on the older rocks.

Rocks of systems other than those mentioned are not present in the areas. Four periods of deformation have been recognized: pre-Silurian, post-Applegate, the Nevadan, and the post-Knoxville.

COAL DEPOSITS AND CRETACEOUS STRATIGRAPHY OF THE WESTERN PART OF BLACK MESA, ARIZONA

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The Cretaceous deposits of the western portion of Black Mesa, Navajo Indian Reservation, Arizona, consist of three principal lithologic units: the Dakota (?) sandstone, the Mancos shale, and the Mesaverde group. They form the lower escarpment, the middle slope, and the upper escarpment of the mesa, respectively.

The lowermost or Dakota (?) sandstone is a transgressive continental deposit of sandstones and shales with a coal as the uppermost member. It grades laterally from a thick sandstone in the north to a thin shaly siltstone in the southwest.

The overlying Mancos shale consists of a basal near-shore sandstone containing marine inverte-

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brates, followed by thick off-shore mudstones. The Mancos shale thins to the southwest indicating a shore line in that direction. This shale is shown to represent a time of maximum transgression for the upper sandy portion is indicative of regression.

The uppermost lithologic unit is the Mesaverde group which is shown on the basis of primary structures to consist of a regressive beach sandstone at the base, and deltaic or transition deposits above. The transition deposits consist of many thin sandstones, mudstones, and coals which grade laterally into one another. The overall movement of the sea is one of regression; howeve., many minor transgressions occur which can be seen in the cyclic effect of the coals, sandstones, and mudstones.

The cap rock of the mesa is a massive near-shore sandstone of the Mesaverde group and represents a time of rapid transgression.

The economic possibilities of the coal are discussed.

PILLOW-LAVA STRUCTURE IN AMPHIBOLITE

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Across the Kings River about 30 miles east of Fresno, California, Pine Flat Dam is being constructed under the supervision of the United States Corps of Engineers. Excavation of the overburden and exposure of fresh bedrock uncovered unsuspected structural and textural features. This paper describes these features and the mineralogic changes which probably occurred during the metamorphism of the pillow basalt.

The regional geology is typical of the Sierra Nevada foothills with metamorphosed sedimentary and igneous rocks intruded by basic to acidic batholiths and dikes.

In the exposed amphibolite bedrock the pillows appear as distorted elliptical and elongated rock lobes, 1 to 8 feet in diameter, separated by thin wavy lines which resemble perlitic structure. Closely associated with the pillows are conspicuous vesticular tubes, irregular vugs, and subrounded amygdules, now filled with white mineral aggregates of quartz and anhedral feldspar. Areas of well-developed pillows are spotty. They usually occur in areas of deep surface weathering where the recent joint planes are zeolite-coated. After close observation and plotting of the pillow structure it is inferred that the original pillow basalts do not represent a series of uniform partially submarine surface flows discharged from a single vent, as the surface physiography falsely indicates, but are more representative of erratic near-surface submarine injections discharged from different vents. It is surprising that some of the features of the original pillow basalt are still preserved, even though the rock body has been subjected to polymetamorphism.

NEPHRITE IN MARIN COUNTY, CALIFORNIA

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First known occurrence of nephrite in northern California is in Marin County where it forms veins and lenses of variable lengths and thicknesses in massive and sheared serpentine. The nephrite varies from pale olive green through light bluish green to dark bluish green. In places it is intergrown with white fibrous tremolite and forms all gradations from tremolite through seminephrite to nephrite. Nephrite veins cut narrow veins containing a mixture of actinolite, talc, and chrysotile. Four stages in mineralization are recognized: (1) formation of serpentine, (2) fracturing and shearing of serpentine with deposition of veins of fibrous serpentine and veins of mixed actinolite, talc, and chrysotile, (3) deposition of nephrite and fibrous tremolite, and (4) post-nephrite deformation and shearing.

RIEBECKITE FROM ST. PETER'S DOME, COLORADO

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The alkali amphibole first described by König as arfvedsonite and later called riebeckite by Lacroix from St. Peter's Dome, Colorado, pegmatites has been reinvestigated. Large black prismatic riebeckite crystals are associated in these pegmatites with microcline, albite, zircon, astrophyllite, and fluorite. A chemical and optical study shows it to be a true riebeckite. Analysis: SiO_2 50.58, Al_2O_3 1.53, TiO_2 0.28, Fe_2O_3 16.15, FeO 14.53, MnO 1.23, MgO 0.49, CaO 0.41, Na_2O 9.97, K_2O 2.17, H_2O + 0.72, H_2O − 0.10, F_2 2.67, less O for F_2 1.13, total 99.70. Optical data: $\alpha = 1.687$, $\beta = 1.691$, $\gamma = 1.696$, $\gamma - \alpha = .009$, $2V = 70°$ (−), r > v extreme, $x \wedge c = 5°$, x = indigo blue y = blue, z = yellow green, x > y > z, optic axial plane || to (010). All reliable analyses of riebeckite were calculated on the basis of 24 (O, OH, F), and it was found that the majority of these did not fit the formula given; instead the formula $Na_4Fe_2Fe_2(OH)_2Si_8O_{22}$ and in a few instances the formula $Na_4Fe_2Fe_2(OH)_2Si_8O_{22}$ appears to be more applicable; this would seem to depend on the amount of Na and K occupying the AA′ position of the amphibole lattice.

LAUMONTITE FROM ANCHOR BAY, MENDOCINO COUNTY, CALIFORNIA

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A zeolite occurring as cement in Cretaceous (?) sandstone from Anchor Bay, Mendocino County, California, has been identified as laumontite by x-ray analysis. Its optical properties vary markedly with the degree of hydration. Completely hydrated, it has the axial plane || {010}, 2V about X = 45° ± 5°, Z ∧ c axis = 10°, $\alpha = 1.515 \pm .003$, and $\gamma = 1.525 \pm .003$. Dehydrated at 100° C., or at room temperature in a dry atmosphere, the laumontite changes to the variety caporcianite or leonhardite with the following properties: axial plane || {010}, 2V about X = 30–35°, Z ∧ c axis = 32–34°, Z′ ∧ c axis on {110} = 39–41°, $\alpha = 1.506 \pm .003$, and $\gamma = 1.517 \pm .003$. By placing it in water, this dehydrated material is readily hydrated again with a resultant change in the optical properties, most notably in the angle of extinction. Other laumontites also undergo such changes but at different rates, and this probably accounts for the variation in properties recorded for laumontite in most references. It is to be expected that laumontite seen in thin section will be the partially dehydrated variety leonhardite because dehydration occurs during the preparation of the section if not before.

None of the laumontites examined has more than two cleavages, namely {110} at an angle of approximately 86°. The statement found in all reference books that laumontite has perfect {010} cleavage is probably the perpetuation of an original error.

GLOMEROBLASTIC AGGREGATES AS AN INTERMEDIATE STAGE OF CRYSTALLOBLASTIC GROWTH

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The term glomeroblastic has been used to describe groups of porphyroblasts of the same mineral. In the earlier stages of crystalloblastic growth these groups of crystals may be merely aggregates then with further development the individual crystals coalesce to form a single larger crystal which may in outline show sharp re-entrant angles as a result of the irregular growing together of several individuals. With continued development the irregular outline may be modified or disappear and a single crystal be formed. In this larger crystal however the twinning and other structures of the smaller individual crystals may persist and thus clearly indicate its composite nature. In the later stages of development the features of the smaller individual crystals tend to be obliterated and only a mottled appearance of the large crystal gives a clue as to its former composite character. Recognition of these features of crystalloblastic growth are an aid in distinguishing the microtextures of metasomatic rocks from those of orthomagmatic rocks.

PALEN MOUNTAINS GYPSUM DEPOSIT, RIVERSIDE COUNTY, CALIFORNIA

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A large deposit of gypsum 5 square miles in area is located at the north end of the Palen Mountains. Interbedded gypsum, marble, quartzite, feldspathic quartzite, and lime silicate rocks, together with metamorphosed intrusives, are arranged in bands trending east-west. The rocks are intensely deformed and metamorphosed. Intense folding, faulting, brecciation, and shearing occurred as a result of intense deformation. These structures vary in magnitude from the large mappable units down to those microscopic in size. Along with the extreme deformation, the area has been subjected to regional, contact, and metasomatic and hydrothermal metamorphism in that order.

The gypsum occurs as massive beds of finely crystalline material of very high grade interbedded with marble or as thinly laminated gypsiferous epidotic schists. Little anhydrite is found at the surface and its presence at depth cannot be ascertained for no drilling has been done. Although the gypsum is of high quality, its value is lessened by the presence of large and small fragments of marble which are literally "floating" in the gypsum beds. These "Tectonic" impurities will increase the cost of mining.

The deposits have been variously dated as Precambrian and as Paleozoic. The lack of fossils and the small amount of geologic work done in the southeastern Mojave desert make dating and correlation difficult. The deposits are similar to those in the Little Maria and Maria Mountains to the east with an upper Paleozoic age designation probably the better alternative. The possibility should be considered that these gypsum, marble, schist, and quartzite beds are the deformed and metamorphosed equivalents of the gypsum, limestone, shale, and sandstone of the Kaibab and Moenkopi (Permian and Triassic) formations in Southern Nevada.

URANOAN THORITE AND THORIAN MONAZITE FROM BLACKSAND PAYSTREAKS, SAN MATEO COUNTY, CALIFORNIA

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Small quantities of uranoan thorite (UO_2 = 6.95%) and thorian monazite (ThO_2 = 4.22%) have been found in blacksand paystreaks distributed in thin sheets and narrow lenses, repeated many times in depth, on the backshore zone of some San Mateo County, California, beaches. These minerals are usually associated with green, brown, red-brown hornblendes, various orthorhombic and clinopyroxenes, chromian spinel, a range of garnets, and zircon, although diamond, in grains of octahedral habit and fragments with pronounced conchoidal fractures, is a noteworthy constituent of the finest grade size of one sample. Pyrite, monazite, clinozoisite-epidote are locally abundant, whereas xenotime, dufrenite, chrysoberyl, pumpellyite, and cassiterite are rare but of considerable mineralogical interest.

The thorite is metamict with $n = 1.846 \pm 0.002$ in most instances, although a range of 1.843–1.851 was observed. $D_{25°C.} = 6.27$. Color is very pale green to brown. Heating induces the production of patchy anisotropism, an increase in refractive index (1.867–1.878 after being held at 680°C. for 2½ hours), a marked transformation in color, but insignificant density changes.

Employing the logarithmic formula of Holmes an age of 24.7×10^6 years has been obtained from the Pb ratio.

The associated thorian monazite is found as slightly worn anhedra of pale yellow color; $\alpha = 1.787$, $\gamma = 1.840$.

Pure fractions of thorite and monazite have been fractionated from the sands and then analyzed completely.

PHOSPHATE MINERALS FROM BRAZIL: A PROGRESS REPORT

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Dark phosphate minerals occurring in the beryl-tantalite pegmatites of northeastern Brazil have been indiscriminately called "arrojadite" by the local miners. Preliminary study has shown that these may be any one of a number of phosphates, some of which have been recognized, while others are as yet unidentified.

Graftonite has been found in at least five localities: Socêgo, Lagoa do André, Poço da Craibeira, Tabôa, Quixabeira. It is ordinarily partially altered to a series of minerals, more or less in the following order: sicklerite (or ferri-sicklerite), heterosite (or purpurite), Huréaulite, phosphosiderite (brilliant blue and called vivianite in some descriptions of the area), variscite, stewartite. These known minerals are sometimes accompanied by unknowns, such as possibly rockbridgeite or dufrenite. At Quixabeira the only alteration minerals are an unknown, green, micaceous mineral, and phosphosiderite.

Lithiophilite was observed at Boqueirão and Patrimonio, altering to essentially the same series as above.

Triplite from Socêgo alters to phosphosiderite and landesite (?), while at Carnaubinhas and Poço da Craibeira it was found only in the unaltered state.

Specimens collected at Urubú and Belo Horizonte showed none of the original mineral, but only massive sicklerite and heterosite.

BASTNAESITE DISCOVERIES NEAR MOUNTAIN PASS, CALIFORNIA*

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A deposit containing large amounts of the rare mineral bastnaesite (a fluo-carbonate of rare-earth elements) was discovered in eastern San Bernardino County, California, in 1949 by Clarence Watkins and Herbert S. Woodward of Goodsprings, Nevada. This and later discoveries appear to indicate a significant new source of the lanthanide metals; cerium, lanthanum, and related rare earths.

Bastnaesite occurs in veins in which calcite, barite, bastnaesite, and quartz are the dominant minerals. Iron oxides, ankerite, and siderite are locally abundant. Fluorite is a widespread minor constituent of the veins. A light-brown to reddish mineral with marked polysynthetic twinning is common in some veins and has been tentatively identified as barytoceletite. Bastnaesite crystals range from microscopic size to tabular crystals more than 4 inches across.

Precambrian gneisses of the Mountain Pass district are intruded by several varieties of younger igneous rock. Syenitic rocks are the dominant intrusives and range from leucocratic types to such mafic varieties as shonkinite. Locally riebeckite and aegerite indicate the alkaline nature of the syenites. At the site of the original discovery the bastnaesite veins are restricted to a body of shonkinite and to the contact zone of the shonkinite with the enclosing metamorphic rocks. Numerous thin dikes of normal leucocratic syenite, lamprophyre, and fine-grained granite are closely associated with the shonkinite. Probably all are products of the same general period of igneous activity.

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Field evidence in this district and the known association elsewhere of cerium and lanthanum with alkaline syenites suggest that the bastnaesite-bearing veins are genetically related to the syenitic intrusives.

DEVELOPMENT OF MELANTERITE AND FIBROFERRITE FROM GELATINOUS FERROUS SULFATE

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Vadose water descending through the oxidized and sulfide zones deposited stalactites and stalagmites of gelatinous ferrous sulfate in the lower workings of the old Commonwealth Mine in the Steamboat Hills, Washoe County, Nevada. Some stalactites grew to a length of 40 cm. and a diameter of 15 cm.

In the presence of water weakly charged with sulfuric acid the gel crystallized into melanterite. Fibroferrite was formed by the oxidation and hydration of part of the melanterite when the acid water became diluted. Upon further dilution of the water the fibroferrite was partly hydrolyzed. The four stages noted above were developed within 5 weeks.

Laboratory experiments indicate that fibroferrite will form from melanterite in very dilute sulfuric acid at temperatures below 15° C. Fibroferrite will not readily hydrolyze in the presence of sulfuric acid with a pH of 5.0 or stronger.

This genetic sequence emphasizes the affect of acids and their strengths on the minerals formed during the oxidation of a sulfide ore body.

FREQUENCY DISTRIBUTIONS AS A TEST FOR THEORIES OF ZONING IN PLAGIOCLASE*

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Normal oscillatory zoning in plagioclase phenocrysts in a monzonite dike near Hyder, Alaska, was studied quantitatively by Homma's method, using albite twinning. Graphs showing variation in anorthite content across 18 to 27 phenocrysts in each of four thin sections, and frequency distributions of the range in anorthite content of 292 single normal oscillatory zones were prepared. The zones were classified into 3 per cent range groups. Hypotheses to account for the oscillatory zoning were examined; those involving mixing of magmas or alternate immersion of crystals into different large-scale magmatic environments failed to explain the abundance of zoned crystals, recurrence of zoning, and absence of resorption. Hypotheses involving only supersaturation and diffusion failed to predict the observed frequency distributions. The hypothesis that appears to predict the qualitative and quantitative features is as follows: Plagioclase crystals grew in magma with slow diffusion. The magma was incompletely stirred at irregular intervals. During intervals between stirring, the magma near the crystals was brought into equilibrium through precipitation of excess calcium as the anorthite-rich part of a zone. Repeated stirring brought magma with excess anorthite to the crystal and formed the normal oscillatory zones. In addition hornblende crystals reacted with the magma to form biotite; this reaction released calcium to form small volumes of high concentration. This process resulted in rare very anorthite-rich zones.

FURTHER BIOGEOCHEMICAL DATA FROM THE SAN MANUEL COPPER DEPOSIT, PINAL COUNTY, ARIZONA

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Although the copper and zinc contents of plants in the vicinity of the San Manuel Copper Deposit are not particularly high they are much higher than those of similar species in similar climatic areas remote from copper mineralization.

Some plants, notably California poppy, paloverde, creosote bush, and scrub oak may be useful to the biogeochemist: others such as the saguaro and ocotillo appear from this preliminary study to be less promising.

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BATHYMETRIC DISTRIBUTION OF SOME SHALLOW-WATER FORAMINIFERA IN THE GULF OF MEXICO*

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A detailed study of some shallow-water Foraminifera of the Gulf of Mexico off the coast of western Louisiana shows a frequency distribution that permits division into bathymetric zones of 30–55, 55–75, and 75–130 feet and to predict positions even within these intervals. A plot of the frequency curves against changes in depth, temperature, chlorinity, and median grain size of the sediments shows no correlation with temperature and median grain size. Chlorinity apparently plays an important role in determining the distribution of several species of *Rotalia* and *Elphidium*. *Rotalia* exhibits its greatest development in areas where the chlorinity is between 12 and 18 parts per thousand; it thrives in waters elsewhere with a chlorinity as low as 5, according to other sources. Three species of *Elphidium* are quite tolerant toward changes in chloride content inasmuch as they are abundant in both brackish and normal-salinity environments. A fourth species of *Elphidium* is mostly restricted to waters of normal salinity. The other faunal-frequency gradations correlate with depth changes generally, perhaps in relation to the amount of light penetration and bottom plants.

Asterigerina carinata d'Orbigny is rather characteristic of bottom prominences. The weight percentages of Foraminifera in the sediment and the numbers of species increase away from shore.

TEST WALL MICROSTRUCTURE AS A BASIS FOR SEPARATING *NONION* AND *ELPHIDIUM*

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The genus *Nonion* Montfort has long been considered to have given rise to the later-appearing genus *Elphidium* Montfort through the development of septal bridges and sutural and apertural pores. The discovery by Wood that these two genera are separable upon the basis of radially built walls in the latter and granular walls in the former raised the question, will the two genera show an intergradation of microstructure in the Eocene epoch, the time of appearance of the first members of *Elphidium*?

Examination of the wall structures of many species of *Elphidium* from samples ranging from Oligocene to Recent produced only one with granular walls, and in this the test appeared to be recrystallized. A number of species of *Nonion* from the Tertiary showed a characteristic granular wall structure; however, several Eocene species which showed incipient features of *Elphidium* have clearly defined radial walls. The assignment of the intermediate forms to either genus is hardly reasonable, for there are no retral processes and only bare rudiments of sutural pores, whereas the aperture is made up of pores at the base of and scattered upon the last septal face with or without the arched opening typical of *Nonion*. Hence, the genetic affinity between the two genera seems to be strongly corroborated by an intermediate category which itself deserves generic status.

SIGNIFICANCE OF TEMPERATURE UPON THE FORAMINIFERA FROM THE DEEP BASINS OFF THE SOUTHERN CALIFORNIA COAST

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Cores from 11 deep basins and 2 additional cores from the open ocean, at depths corresponding to the deepest basins, have been taken off the southern California coast. Additional small bottom samples have been examined. Temperature, oxygen content, and salinity were measured at depth in most of these basins. Four foraminiferal biozones based on temperature readings have been proposed. The physical and chemical conditions that existed in the Los Angeles Basin during Pliocene time have been partially reconstructed from these data.

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RECENT MOLLUSCA AND TERTIARY CORRELATIONS

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Data on the duration of planktonic larval stages of mollusca indicate that most of them will last only about 3 weeks. Thus with current speeds comparable to that of the Gulf Stream over much of its path, a significant proportion of a fauna may be expected to be transported over oceanic depths for a maximum of about 900 miles. Thus fossil faunas separated by over 900 miles of oceanic depths cannot be expected to have many identical species.

Where areas are connected by shallow-water migration routes, the relationships of faunas are much more marked. Twenty-six per cent of the pelecypods and 15 per cent of the gastropods living at San Diego are also living at the latitude of Puget Sound, about 1000 miles away and with 7°C colder temperatures. Thirty pelecypods and 26 univalves found at San Diego live along the Pacific Coast through 40° latitude. In the Tertiary, Vredenburg has recognized 58 species out of a fauna of 107 species from the Oligocene of northwest India as occurring either in the form of identical (43) or closely related species in Europe, a distance of about 3000 miles along the shallow-water Tethyan seaway.

With respect to the occurrence of one or two identical species in areas widely separated by oceanic depths, Hertlein has listed about 29 Recent species that occur on the western shores of the Americas and in the Indo-Pacific. These and similar data provide a yardstick for evaluation of Tertiary correlations.

FORAMINIFERA OF THE "SIDNEY", NORTONVILLE, AND KELLOGG SHALES

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The "Sidney", Nortonville, and Kellogg shales belong to the upper portion of the Eocene Series of Central California. The first two lithologic units, separated by about 2500 feet of sandstone, are best exposed in Markley Canyon, on the northeast flank of Mount Diablo. The Kellogg shale, the lateral equivalent of the Nortonville shale, is best exposed in Kellogg Creek approximately 15 miles to the southeast.

Two hundred and seventy-five foraminiferal species belonging to 70 genera and 22 families recognized from the above lithologic units are grouped into several faunules, reflecting a bathymetric and temperature variation from warm-shallow to deep-cool water.

Laiming's foraminiferal zones A-1 and A-2 are easily recognized, zones B-1 and B-2 may possibly be represented in the lower portion of the Nortonville shale.

AMMONOID FROM LAKE TAHOE, NEVADA

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A beach pebble from the northern end of Lake Tahoe containing an impression of part of an ammonoid cephalopod is evidence of the Mesozoic age of metasediments in the lake basin. The fossiliferous pebble is a banded siltstone, now converted to hornfels similar to beds found at Mount Tallac at the south end of the lake.

Known Mesozoic rocks in the region are the fossiliferous Sailor Canyon formation of the Sierra, and *Monotis*- and *Arietites* ?-bearing beds in El Dorado Canyon south of Dayton, Douglas County, Nevada. *Monotis*-bearing beds are found in the Yerington district 25 miles farther southeast.

Sedimentary and metasedimentary rocks in the Tahoe area have previously been classified as Mesozoic because of their striking lithologic similarity to the Sailor Canyon and similarity of structural trend. The finding of this ammonoid helps establish the age of the sediments. It is the first marine fossil reported from the Tahoe basin.

The Tahoe area lies midway between the type locality of the Upper Triassic-Lower Jurassic Sailor Canyon formation and equivalent beds in El Dorado Canyon. Therefore it is critical in the study of Mesozoic rocks in the region.

HELICOPRION FROM ELKO COUNTY, NEVADA

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An example of the selachian tooth structure *Helicoprion* with associated fusulinids from the vicinity of Contact, Elko County, Nevada establishes the Permian age of beds previously known only as Carboniferous. Beds stratigraphically above *Helicoprion*-bearing quartzites contain fusulinids identified as *Parafusulina*. This indicates that the beds at Contact are Leonardian, or Guadalupian; specific identification of these fusulinids may permit closer dating of the beds.

Other examples of *Helicoprion* described by Wheeler (1939) and referred to the Artinskian or Uralian, were in otherwise barren tuffaceous material. The Contact fauna not only dates the enclosing sediments but also helps determine the range of *Helicoprion* in North America.

PRELIMINARY STRATIGRAPHIC REPORT OF SOME CALIFORNIA EOCENE SILICOFLAGELLATES

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A study of two silicoflagellate faunules from the "Sidney" and Kellogg shales of upper Eocene age near Mount Diablo, California, indicates that these organisms may have potential stratigraphic value. This statement is based on the following facts: (1) The samples studied contain species which make their first appearance, and species which make their last appearance, in these two faunules. In addition species are restricted to certain horizons, indicating the possibility of short geographic ranges. (2) The two faunules contain species from more than a dozen widely separated countries in five continents. (3) Most silicoflagellates are distinctive and therefore easy to identify.

NAUTILOID *RAYONNOCERAS* IN CALIFORNIA

Joseph H. Peck, Jr.
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Several collections of fossils from the Tin Mountain area of Death Valley National Monument include a large "orthoceratoid" nautiloid of a type previously unreported west of the Mid-Continent region. The specimens are referable to the Mississippian genus *Rayonnoceras*, a member of the Actinoceratida, an order most commonly found in the Ordovician. Projection of the angle of the conch shows that the largest individual could have been at least 600 mm. in length, with a corresponding diameter of 110 mm.

The associated fauna appears to be a correlative of the White Pine shale of Nevada and the Caney shale of Oklahoma, both upper Mississippian.

INSECT FOSSILS IN ONYX MARBLE, AND MODERN ENTRAPMENT IN CALCITE WATERS

W. Dwight Pierce
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A series of very primitive fossil insects—pedipalpids and a millipede and centipede—have been found in onyx marble in a quarry in Northern Arizona. The onyx-marble waters were forced upward into cleavages in Permian Supai along a fault, catching primitive rock-inhibiting arthropods.

In seeking an explanation for fossils in onyx marble, a hot mineral spring in Imperial County, California was visited, and here many kinds of insects are being killed by the hot waters, and almost immediately coated with crystals. As soon as these become too heavy they drop to the bottom and become a part of the solid crystal body there forming. In this particular site the waters are open and hence the insects caught are all winged.

INITIAL MOTION OF THE FIRST LONGITUDINAL EARTHQUAKE WAVE RECORDED AT PASADENA AND HUANCAYO

Markus Båth

Compression and dilatation of *P* waves have been studied for Pasadena and Huancayo. Among the results, given in a series of maps, may be mentioned that for the Aleutians the shallow shocks give dilatation and the intermediate shocks compression at Pasadena, probably indicating a larger dip angle of the fault plane for the intermediate than for the shallow shocks. The distribution of compression and dilatation for all earthquakes along the Pacific from Alaska to Central America indicates a southward motion of the continent relative to the Pacific. For South America as well as for the west to southwest side of the Pacific Ocean the distributions of compression and dilatation are complicated but nevertheless show quite definite regularities. For earthquakes well within an area of either compression or dilatation we get a clear first motion of *P*, whereas for earthquakes within mixed areas and for earthquakes on or in the vicinity of boundary lines between areas of compression and dilatation this is generally not the case. It is suggested that similar data be compiled for a large number of seismic stations, after which the results could be brought together to give more definite information about the tectonics of the earthquake regions.

FURTHER IMPROVEMENTS IN A CAPACITY-TRANSDUCER SEISMOGRAPH

Hugo Benioff

Seismological Laboratory, Pasadena, Calif.

The capacity-transducer seismograph described in the previous meeting has been considerably modified. In its present form the mechanical moving member is positioned between two fixed capacitor plates so that motion of the member produces capacity increments of opposite sign in the two condensers formed between the fixed and moving members. The two condensers are shunted by inductances of equal size so mounted as to have low mutual coupling. The two tuned circuits thus formed have the same resonant frequency—approximately 10.75 MC. The two inductors are coupled to the output circuit of an electron-coupled frequency doubling crystal oscillator operating at 5.35 mega cycles fundamental frequency. When the moving mechanical element is positioned midway between the two fixed capacitor plates the two circuits are each detuned 50 KC from resonance, at which point they each have currents approximately 0.7 times the values at resonance. The two tuned circuits operated two oppositely poled germanium crystal diodes whose rectified outputs are connected to a resistive bridge circuit. Output from the bridge at seismic frequencies is taken through a large capacitor which with the bridge resistors has a time constant of 100 or 1000 seconds depending upon the application. The instrument has demonstrated good stability for use with galvanometers having periods from 0.1 second to 15 seconds. With 90-second period galvanometers the stability is not yet satisfactory. Operating on a pendulum with 1-second period the transducer output is approximately 10 times the maximum required to drive a 0.1-second galvanometer for satisfactory recording of short-period microseisms at Pasadena.

SOUND WAVES IN THE ATMOSPHERE GENERATED BY A SMALL EARTHQUAKE

Hugo Benioff

Seismological Laboratory, Pasadena, Calif.

An earthquake of magnitude 5.8 which occurred on January 24, 1951, in the Imperial Valley California, approximately 280 km from Pasadena, generated atmospheric sound waves which were recorded by the electromagnetic microbarograph at Pasadena. Slides of the recorded waves will be shown.

MECHANISM OF EARTHQUAKE GENERATION

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Measurements of ground displacements associated with the San Francisco earthquake of 1906 have indicated that the strained volume of rock which provided the energy of the earthquake was confined to a narrow zone extending to not more than 10 km either side of the fault. In view of the length of the active segment of the fault, such a narrow zone of strain requires the effective elastic constant of the rock within the zone to be less than one-tenth that of the surrounding rock. A configuration is proposed to explain the reduced elastic stiffness, and some of the consequences of this mechanism are discussed. These include (1) the maximum available energy for the generation of earthquakes, (2) on a given fault the possibility of strain relief by small shocks, (3) the fault as a zone of discontinuity for waves passing through it, (4) the duration of an earthquake as a function of size of strain zone, (5) the nature of the generating movement as revealed by identical earthquake pairs, and (6) evidence from earthquake sequences for large strains in the rock outside the earthquake-generating strain zone.

VALLEY WAVE

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Earthquakes of Richter magnitude greater than 3 with epicenters in the Coast Range Mountains west of the San Joaquin Valley produce an unusual record on the Fresno seismograph which is located on the thick valley sediments. Late in the record a second set of body waves arrives. These are followed by large-amplitude surface waves: first Rayleigh then Love. Many records exhibit two distinct sets of these slow surface waves.

The apparent velocity of the surface waves is least for quakes with epicenters nearest the edge of the valley. This indicates that these waves are set up in the sediments near the edge of the valley. A velocity of about 0.5 km/sec is obtained for these waves.

The velocity and dispersion of the Love waves is consistent with the following structure: a layer of 1000 feet of sediments with a density of 2.0 gm./cm^3 in which S has a velocity of 0.4 km/sec, over a great thickness of sediments with a density of 2.5 gm/cm^3 in which S has a velocity of 0.7 km/sec.

SURFACE WAVES AT HONOLULU

Maurice Ewing and Frank Press
Lamont Geological Observatory (Columbia University), Palisades, N. Y.

A study of surface waves arriving at Honolulu along the four cardinal directions from the circum-pacific belt was undertaken following a suggestion by Neumann.

It is concluded in agreement with previous results that the Pacific Basin transmits Rayleigh waves according to the theory for a water layer overlying a thick layer of ultrabasic rock. It transmits Love waves like a thin layer of ultrabasic rock over a thick layer of slightly higher-speed rock. Striking differences from the simple surface-wave character for some shocks are attributed to differences in excitation at the focus rather than to differences in transmission. Strong excitation of the second mode of Rayleigh waves and Love waves explains the observations.

SURFACE WAVES FROM ATLANTIC EARTHQUAKES

Maurice Ewing and Frank Press
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The dispersion of Rayleigh waves from Mid-Atlantic Ridge earthquakes recorded at Palisades has been found to fit the dispersion curve for a water layer over a thick body of ultrabasic rock.

Supplementary reading of seismograms from other stations supports this conclusion, correction for continental path being made by use of J. T. Wilson's dispersion curve.

It is pointed out that the Mid-Atlantic shocks produce strong surface waves with period range 40 to 15 seconds like those of the Southwest Pacific and in contrast to those of the West Coast of the Americas.

SURFACE WAVES FROM SOLOMON ISLANDS EARTHQUAKE, 24 JULY 1950

Maurice Ewing and Frank Press
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Seismograms for Pacific Paths from Honolulu, Berkeley, Tucson, and Palisades were studied. Rayleigh waves of periods 38 sec. to 14 sec. had group velocities from 4.0 km/sec to 1.5 km/sec following closely the theoretical curve for an ocean 5.5 km deep over bottom of density 3.0 gm/cm^3 and shear-wave velocity 4.35 km/sec. A correction for the continental portion of the path using J. T. Wilson's results, was applied for Tucson and Palisades.

Rayleigh waves travelling the major arc of the great circle across the Indian and Atlantic oceans follow the same theoretical dispersion curve, when allowance for the continental portion of the path is made.

The wide range of Rayleigh-wave group velocities, obtained by taking proper account of the ocean, explains completely the duration, period, and general rhythmical character of the coda.

TIDE-GAUGE DISTURBANCES FROM THE GREAT ERUPTION OF KRAKATOA

Maurice Ewing and Frank Press
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The aerial disturbance from Krakatoa was recorded at many stations on at least three passages around the earth. A tidal wave on the ocean was recorded at tidal stations in almost all parts of the world. Only at near-by stations did the arrival times uniformly agree with that expected for gravity waves in the ocean; many distant arrivals were attributed to coincidental local earthquakes etc.

It is shown that the tidal disturbances at distant stations either coincide in time with the first aerial arriving at the station in the direction from ocean to continent or are delayed a few seconds, a result which would be expected from coupling between compressional waves in the atmosphere and gravity waves in the ocean.

These observations have led to theoretical and experimental investigations of several types of air-coupled surface waves.

FURTHER OBSERVATIONS OF THE T PHASE

Maurice Ewing, Frank Press, and J. Lamar Worzel
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A large number of *T* phase readings have been obtained from the Honolulu Neumann-Labarre seismograms of earthquakes of the circum-Pacific belt. Owing to negligible corrections for land paths, the phase appears as a brief train of short-period ($<\frac{1}{2}$ second) waves whose maximum can be read with a probable error of a few seconds. The velocity and period (1.46–1.50 km/sec) support the theory that this phase is propagated as sound waves in the water.

T phases observed at Bermuda for several Antillean shocks show similar results.

SURFACE WAVES RECORDED BY A BENIOFF VECTORIAL SEISMOGRAPH

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Seismological Laboratory, Pasadena, Calif.

The Benioff vectorial seismograph which is operated in connection with the microseismic project sponsored by the Geophysical Research Directorate of the Cambridge Field Station, AMC, U.S. Air Force, has recorded a number of distant earthquakes at Pasadena. In teleseisms with trans-Pacific wave paths the surface waves begin with Love waves (with decreasing periods) lasting for a few minutes only. They are followed by Rayleigh waves which persist frequently for more than an hour and exhibit waves with decreasing periods at first but practically constant periods later. The vibrations are in the direction toward the source within about 10 degrees. Records from Central American shocks exhibit surface waves with frequently changing pattern including movements perpendicular to the direction toward the source, in this direction and more complicated motion.

TRAVEL TIMES OF WAVES FROM ARTIFICIAL EXPLOSIONS

B. Gutenberg
Seismological Laboratory, Pasadena, Calif.

Records of five explosions in Nevada, January 27 to February 6, 1951, were investigated. The co-ordinates of the sources and the origin times were determined by the method used in earthquakes. Travel times were plotted together with the times from the Corona blast, August 6, 1949. The agreement is good, and the inferred structure of the crust agrees closely with that described in the paper *Travel times of blasts in Southern California* (Seismol. Soc. Am., Bull., 1951, in press). The waves at greater distances considered previously to be *S* waves are probably surface waves. As in other records from sources located at the surface no clear phase corresponding to $\bar{P}$ in earthquake records was found. This is to be expected if $\bar{P}$ is a channel wave travelling along a low velocity layer at a depth near that at which earthquakes in the region originate.

SEISMIC-REFRACTION MEASUREMENTS IN THE ATLANTIC BASIN, PART II

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During the summer of 1950 seventy refraction profiles (forty-seven reversed) were made by the Columbia geophysics group in co-operation with the R/V ATLANTIS and R/V CARYN. Seven of those profiles (four reversed) made on a 300-mile line southeast from Bermuda are presented. A high-speed basement is found on each profile with a velocity of about 6.8 km/sec. On the two longest reversed profiles a deeper layer was determined at a depth of about 4.6 km and a velocity of 8.1 km/sec. Above the high-speed basement an unconsolidated sedimentary velocity of 1.7 km/sec was found on one profile, and on all those profiles which have the appropriate shots the high-speed basement line breaks into a lower-velocity line of 4.3 km/sec and at a depth corresponding with the "M" reflection horizon. (All velocities and depths are tentative and are subject to the final least-square solution.)

TWO SLOW SURFACE WAVES ACROSS NORTH AMERICA

Frank Press and Maurice Ewing
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A short-period surface-shear wave from a West Coast earthquake is recorded at Palisades, with a velocity of about 3.4 km/sec at periods of 2 to 3 seconds. These waves are followed after about a minute by longer waves (period 8 to 10 sec) of the same type.

From these same earthquakes there is observed a Rayleigh wave with a velocity of about 3.0 km/sec at periods of 8 to 10 sec. Both are large amplitude phases and are well recorded on shocks for which no earlier phases can be detected. The earlier phase often has an abrupt beginning. An explanation in terms of wave-guide transmission through the crust is given.

CHECK LIST ON EARTHQUAKES WITH SURFACE FAULTING

C. F. Richter
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Shocks known to have been accompanied by surface fault displacement are listed. The best authenticated instances with large motions are: Alaska, 1899; California, 1857, 1872, 1906, 1940; Nevada, 1915; Mexico, 1887; Peru, 1946; New Zealand, 1855, 1888, 1929; Formosa, 1906, 1935; Japan, 1891, 1927, 1943; Baluchistan, 1892; India, 1819, 1897; Anatolia, 1939. Complex, small, and doubtful instances are discussed. The sense (right or left hand) of strike slip is specified where possible.

EARTHQUAKE MAGNITUDE DETERMINATION AT ROME, ITALY

C. F. Richter
Seismological Laboratory, Pasadena, Calif.

Di Filippo and Marcelli have lately published two papers bearing on the magnitude scale. Magnitudes of teleseisms determined at Rome agree almost perfectly with findings at Pasadena, with a station constant of +0.4. A scale has been set up for the Italian region based on the seismograms of Wiechert instruments; magnitudes thus determined conform closely with those deduced from other data, but the calculated energies are too low, probably because of the low magnification of the Wiechert for short periods.

TERTIARY BASIN DELAY AT FRESNO, CALIFORNIA

Don Tocher
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Anomalies have been noted between the observed times of arrival of preliminary waves at Fresno from epicenters in the California Coast Ranges. These are examined in the light of distant earthquake data.

ABSTRACTS OF PAPERS SUBMITTED TO MEETING OF ROCKY MOUNTAIN SECTION IN RAPID CITY, APRIL 13–14, 1951

DEVELOPMENT OF DAKOTA BASIN IN SOUTH DAKOTA

Charles Laurence Baker

State Geological Survey, Vermillion, S. D.

Paleozoic Colorado land mass extended from northern Black Hills nearly to El Paso, Texas. Sioux quartzite ridge, forming southwest lobe of continental nucleus, was generally emergent since Mid-Ordovician. Between is the Dakota or continent's largest nongeosynclinal basin. Until end of Pennsylvanian, Dakota Basin was subsiding, in increasing amounts to northward. Permian and Trias times show more stability. Lower upper Jurassic sea reached eastward beyond State's center. Upper Cretaceous witnessed increasing downtilting to westward, into Cordilleran geosyncline, most of it during Neumayer's Cenomanian transgression lasting to mid-Turonian (embracing Graneros formation). Basin downwarping recurred during Laramide and later orogenies, evidently in ancient zone of weakness. Structural relief on base Pennsylvanian along north half west State line amounts to 11,500 feet. Paleozoic is 4700 feet thick beneath State's northwest corner.

PEDIMENT BROADENING IN SOUTH DAKOTA BADLANDS

Charles Laurence Baker

State Geological Survey, Vermillion, S. D.

Viewed from spur tops it can be noted that a large proportion of existing drainage channels flow along spur bases at edges of broad denuded flats. It should be obvious that greatest erosive force of water is at foot of greatest slope generating greatest velocity. Sheet wash during greater intensity rainfall scoops out base of bare slope at same time it scours surface of bare slope above, thus causing recession of interflat spurs. Drainage basins simultaneously lengthen by erosion headward. Same action was first noted by writer 20 years ago in Trans-Pecos Texas.

PLEISTOCENE IN WESTERN SOUTH DAKOTA

Charles Laurence Baker

State Geological Survey, Vermillion, S. D.

Western derived sand and gravel with earlier Pleistocene mammalian fossils form the depositional plain of the White-Niobrara river divide in Gregory and Charles Mix counties near the Nebraska line, where bottom of partly filled-in Missouri River channel is 1000 feet lower. Below depositional plain is a broad old-age valley stage at 1800 feet altitude along Missouri River throughout its course across South Dakota. Wisconsin glaciation and formation of Missouri River are later than the old age valleys.

In the Black Hills is a denuded near peneplain surmounted by late mature stage peaks like Terry, Custer, and Harney. This may be an exhumed Paleozoic surface since scarp of Madison limestone plateau may surmount it on west; the latter shows some evidence of bevelling, which may have been produced during upper Mississippian erosion, and also westward tilting. The oldest near peneplain is well exhibited surrounding the Homestake mine shaft at Lead.

A late old-age broad valley subcycle forms a broad base at foot of Harney Peak, also the boulder-filled flat at 4100–4150 feet altitude 6 miles southwest of Rapid City, the 4250 feet altitude flat 10 miles west-north-west of Rapid City, and in other places. Rapid Creek, with well-developed intrenched meanders, is cut 700 feet deeper than the old-age valleys. The quasi-bevelling of the Dakota-Lakota hogbacks, average altitudes 4000 feet, may have taken place in the old-age valley stage.

No existing South Dakota drainage course is older than Pleistocene.

YARDANGS IN SOUTH DAKOTA BADLANDS

Charles Laurence Baker

State Geological Survey, Vermillion, S. D.

Airplane photos and new Conata topographic map show, between Conata station and Cuny Table, long narrow undrained grooves or trenches excavated in bentonitic clays and loesslike deflation yardangs described by Sven Hedin and Aurel Stein in Pleistocene lake and loess deposits of Tarim Basin, Chinese Turkestan. Their northwest-southeast alignment is parallel to courses of tributaries to the eastward-flowing rivers and longer axes of generally broader deflation hollows throughout the Great Plains province, though the latter are commoner on Texas Staked and Panhandle High Plains.

Dry incoherent bentonitic clays and silts without vegetation are especially susceptible to scour of the strongest prevalent northwesterly winds during the dry winter seasons. Soil scientists now know that wind-deposited loess is a major constituent in parent soil material of most good agricultural areas between Rockies, Alleghanies, and Gulf of Mexico. Since dust in clouds is blown over tops of New Mexico mountains between the Pecos River and Rio Grande much of the wind deposits of interior lowlands is derived from the western deserts which appear to have been their ultimate source from Jurassic time to present.

CHERT AND VOLCANIC ASH EAST OF SIOUX FALLS, SOUTH DAKOTA

Brewster Baldwin

State Geological Survey, Vermillion, S. D.

A formation of chert and volcanic ash crops out east of Sioux Falls along Big Sioux River, and at Corson, S. D., along Split Rock Creek. Both outcrops are near basic igneous intrusions. The former outcrop, on the north bank of the river, plus information from foundation tests for the Northern States Power Plant, indicates a formation at least 60 feet thick, composed of chert, containing woody fragments, sponge spicules, and Radiolaria (?). Six miles east of this, 8 feet of consolidated volcanic ash overlies Sioux quartzite and grades up into at least 4 feet of chert with sponge spicules. The age of the formation is unknown but perhaps Cenozoic.

GEOLOGY OF THE SIOUX FORMATION*

Brewster Baldwin

South Dakota Geological Survey, Vermillion, S. D.

The Sioux formation, at least a mile thick, consists largely of nonmetamorphosed orthoquartzite. Exposures are scattered for 180 miles, between Mitchell, S. D., and New Ulm, Minn.; quartzite has been encountered subsurface west of Chamberlain, S. D., and at Omaha, Neb.

Typical Sioux quartzite is a pink, well-sorted, rounded, medium quartz sand bonded by secondary silica enlargement of the quartz grains; in argillaceous quartzite silica cement is largely microcrystalline. Bedding in parallel planes up to a meter apart is characteristic; cross-bedding between these planes is common. Ripple marks are fairly abundant. Mud cracks are found in some mudstones and argillaceous quartzites, and a similar pattern is known in typical quartzite. Two conglomeratic zones totaling about 500 feet thick, with quartz pebbles, are known; coarser conglomerates, possibly basal, are found in two places.

The formation is preserved in structural basins trending N–NW. to W–SW. on the east-west axis of the Sioux uplift. Dips average 5°, with a maximum of 30°. The formation is pre-Upper Cambrian; no fossils are known. The formation fits descriptions of the Baraboo, Uinta, Prospect Mountain, and some Beltian quartzites.

The sediment was derived from a thoroughly weathered upland to the north; wind probably winnowed much or all of the fines. The iron-oxide coating around the quartz grains is probably residual. The sediment was probably deposited either on a shallow marine shelf or in an interior nonmarine basin; cementation may have been penecontemporaneous.

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DISTRIBUTION OF IMPURE MARBLES AND LIME-SILICATE MEMBERS IN THE IDAHO SPRINGS FORMATION WEST OF DENVER, COLORADO

Margaret Fuller Boos

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The impure marble and lime-silicate members of the Idaho Springs formation described for the Georgetown area (1) have been traced eastward across the Denver Mountain Park area nearly to the Foothills.

The marbles and associated rocks outcrop in three belts up to half a mile across and 7 to 20 miles on strike. The lowest carbonate-bearing zone outcrops discontinuously at the base of the Idaho Springs west of Brookvale along Vance Creek. Some 10,000 feet of biotite-sillimanite schist separates the lowest marble beds from the marble-bearing zone next above. The second one outcrops from Chief Mountain in an arc more than 20 miles on strike southeast to Deermont. Associated metasediments are quartzites, quartz gneiss, mica schist, and lime-silicates.

A third broad belt of marble-bearing strata extends southeastward 10 miles from Santa Fe Mountain to Bear Canyon. It consists of complexly folded calcareous beds, greatly affected by boudinage, interstratified with bedded hornblende gneiss and quartz gneiss. The marbles are exposed on the flanks of isoclinally folded upper Idaho Springs measures. North of Bergen Peak the second and third marble zones are separated 5000 feet stratigraphically, but the interval is less than 1000 feet near Bear Canyon.

The thickness of the Idaho Springs formation is less at the east than at the west due, partly, to thinning out of the biotite-sillimanite section.

EVIDENCE OF A POST-LARAMIDE NORMAL FAULT ZONE NORTH OF THE FERRIS MOUNTAINS, WYOMING

Leo C. Carpenter

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The Ferris Mountains are, in part, the southern boundary of the Sweetwater Arch in central Wyoming. They are bounded on the east by the Seminoe Mountains and on the north by a structural basin called the Granite Mountain graben. They consist of Paleozoic and Mesozoic sediments upturned against a Precambrian core, and are the eroded remnants of the Seminoe overthrust, produced by compression from the northeast.

The Seminoe thrust extends through the Precambrian core to the northern flank of the Ferris Mountains. The thrust plane dips 10° NE. where the Precambrian rocks rest on the younger sedimentary series. This part of the thrust extends southward in a long narrow tongue having a 7-mile horizontal displacement. The youngest rocks involved in the disturbance are Upper Cretaceous. This suggests that the structure is Laramide.

The Seminoe thrust intersects a 25-mile-long west-trending post-thrust normal fault zone along the northern flank of the Ferris Mountains. This normal fault zone generally places Tertiary rocks to the north in fault contact with the Precambrian core of the Ferris-Seminoe mountains.

Granite Mountain graben thus was formed by collapse of the Sweetwater Arch along the northern flank of the Ferris-Seminoe mountains and probably along the southern margin of the Rattlesnake Mountains.

STRUCTURAL SETTING OF THE KENTUCKY-ILLINOIS FLUORSPAR DISTRICT IN THE EASTERN INTERIOR BASIN

D. A. Carter

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Evidence for a curving linear zone of structural disturbances extending from central Pennsylvania through West Virginia and central Kentucky to southern Illinois is reviewed. Since this zone is

characterized by divergence from normal Appalachian structure, transection of the Cincinnati arch, and widely spaced ultrabasic intrusives, it appears deep-seated, probably originating from a Precambrian weakness which has influenced later regional deformation.

The Kentucky-Illinois fluorspar district is on the approximate crest of the north-plunging Cumberland arch. This is the earliest major structure and is characterized by ultrabasic dikes striking north-northwest parallel to the trend of the arch. The dikes occupy tension fractures of small displacement probably produced during folding of the arch by lateral compression. The faults with which the mineralization is connected are later, probably connected with a deep-seated lateral thrust of Ouachita age from the southwest, which, directed upward under the influence of the Precambrian zone, originated the Rough Creek fault zone as shears, with normal faults and grabens occupying the tension position on the Cumberland arch. These structures appear to have been modified or intensified by forces from the southeast connected with Appalachian deformation.

The Kentucky-Illinois fluorspar district is therefore at the intersection of four major structural trends which have produced conditions favorable to the passage of mineralizing solutions and localization of ore deposits. Evidence indicates a remote genetic connection between the dikes and the ore deposits.

PEDIMENTS OF THE GOLDEN-MORRISON AREA, JEFFERSON COUNTY, COLORADO

Charles F. Fogarty

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From five to seven gently eastward-sloping remnants of pediments appear along the eastward-flowing streams in the foothills belt east of the Front Range. Two striking facts in connection with these pediments is their gradual convergence eastward onto the plains and their almost complete absence in the resistant crystalline rocks of the Front Range.

Each pediment consists of an undulating, beveled, debris-strewn surface developed upon Paleozoic to Cenozoic sediments of varying dip. The debris consists mostly of heterogeneous, poorly sorted, unconsolidated fragmental material derived directly from the Precambrian of the Front Range and from the reworking of gravels from the higher pediments. The petrology of the constituent materials differs from stream to stream and reflects variations in the lithologic character of the source rocks so that the correlation of the pediments must be based primarily upon elevation and extent.

The relative importance of successive rejuvenations versus climatic changes, possibly related to glacial and interglacial epochs, are weighed as important factors in the development of these multiple-pediment surfaces.

Criteria for the recognition of the pediments and descriptions of individual surfaces are presented.

STRUCTURE AND ORIGIN OF THE NORTHERN SANGRE DE CRISTO MOUNTAINS, COLORADO

John W. Gabelman

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Reconnaissance of the lower Paleozoic sediments diagonally crossing the northern Sangre de Cristo Range of southern Colorado has disclosed an imbricate zone of east-dipping thrusts associated with normal and transverse faults on both sides of the range. Open folds sharpen southeastward from Wellsville, breaking into thrusts which often repeat the section several times, then die out without transition through folds. Whether the folds at Orient belong to the northern thrust zone or to later structures to the south is not known, but they are considered the southern end of the thrust zone. Two areas offer evidence for shallow thrusting confined to the lower Paleozoic. Transverse faults often displace thrusts. The steep western slope of the range is considered the scarp of a normal fault.

Four ages of Laramide and Tertiary deformation are recorded. The zone of westward-directed thrusting is part of a much broader zone which includes the Pleasant Valley fault and similar thrusts west of the San Luis Valley. This zone is continuous with the early Eocene London-Weston thrust

belt of South Park and the Mosquito Range. The northeast-directed deformation of the Sangre de Cristo Range south of Orient has no counterpart in the northern range. Large normal faults in the Wellsville-Orient thrust zone indicate vertical uplift of a pre-Cambrian area and correlate with late Eocene uplift to the south. Downfaulting of the San Luis Valley from Oligocene to Recent outlined the present trend of the range and explain its divergence from the zone of thrusting.

URANIUM IN BLACK SHALES, LIGNITES, AND LIMESTONES IN THE UNITED STATES*

Garland B. Gott, Donald G. Wyant, and Ernest P. Beroni

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Small quantities of uranium occur in carbonaceous deposits at a great many localities in the United States, but the quantity rarely exceeds 0.1 per cent. The most common uranium-bearing carbonaceous deposits are the black marine shales, principally of Paleozoic age, exposed in the eastern and central parts of the United States. The uranium content of most of these shales ranges from a few thousandths to a little more than 0.01 per cent.

Another type of low-grade uranium-bearing carbonaceous deposit is represented by some of the lignite deposits of Tertiary age in Montana, Nevada, North Dakota, South Dakota, and Wyoming. The uranium content of these uraniferous lignites is comparable to that of the black shales. The concentration of uranium in the lignite ash, however, is considerably greater than in the black shales.

Several widely distributed uranium deposits in limestones, most of which are low-grade, have been discovered recently in Missouri, New Mexico, New Jersey, Utah, and Vermont. The limestones range from Precambrian to Tertiary. In some of these deposits the uranium is associated with phosphatic, carbonaceous, or argillaceous material. In others secondary uranium minerals occur as fillings in fractures and vugs. At some localities the uranium is associated with contact-metamorphic minerals.

PLEISTOCENE OR SUB-RECENT *EQUUS* IN RAPID CITY, SOUTH DAKOTA

Morton Green

South Dakota School of Mines and Technology, Rapid City, S. D.

Workmen excavating ground for a building on the South Dakota School of Mines and Technology campus recovered upper molars of *Equus*. Examination showed that the teeth were found approximately 8 feet below the surface in a pebbly sand. This sand appears to have been laid down by an ancient stream, possibly Rapid Creek, during one of its meanders. Older residents claim no previous excavation or filling has ever taken place on the campus. Specific determination cannot be made from the teeth.

PROBLEMS OF THE MINNELUSA FORMATION IN THE BLACK HILLS

J. P. Gries and D. A. Berg

Rapid City, S. D.; O'Neill, Neb.

The writers have re-examined key surface and subsurface sections of the Minnelusa formation in the Black Hills area and have made isopachous and facies maps in an effort to determine whether the evaporites so common in the subsurface sections are missing over the Black Hills outcrop area because of nondeposition or subsequent solution.

Distribution and relative unimportance of collapse sections on the outcrop, thinning in subsurface toward areas of thin outcrop sections, and consistent increase in clastic ratio toward the outcrop area all suggest that very little of the apparent thinning over the Black Hills uplift is due to removal of beds by solution.

Heavy sandstones on the outcrop and in adjacent subsurface sections apparently had their origin to the north.

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"DRY CREEK FORMATION" IN SOUTHWESTERN MONTANA

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In southwestern Montana, the cartographic unit known as the "Dry Creek" appears to be correlative with the Upper Cambrian Red Lion formation and the probable Devonian Maywood formation of the Philipsburg quadrangle. Characteristic features of the Red Lion formation include (1) a basal shale, (2) limestone pebble conglomerate beds, (3) wavy silty laminations in some of the limestone, (4) Franconian fossils, and (5) tan and/or red coloration. The Maywood consists of tan or red silty dolomites and dolomitic siltstones with local occurrences of sandstone and intergrades with the overlying Devonian Jefferson dolomite. The dual nature of this cartographic unit is emphasized by the presence of an erosional unconformity near its middle.

In a large portion of southwestern Montana the Red Lion-Maywood sequence cannot be subdivided in the field because of (1) poor exposures, (2) obscurity of the characteristic features of the Red Lion due to dolomitization at many localities, and (3) the general similarity of the topographic expression and lithology of the two units.

Inasmuch as Lochman (1950), whose findings in central Montana are corroborated by the writer's studies, has restricted the term "Dry Creek" to the basal shale member, it is suggested that a new name be given the cartographic unit formerly called "Dry Creek" in southwestern Montana.

VEIN QUARTZ IN THE HOMESTAKE ORE BODY

James O. Harder

Lead, S. D.

Relations of vein quartz and ore at the Homestake gold mine in the Precambrian rocks of the South Dakota Black Hills are described.

The attitudes of the quartz bodies and their method of emplacement or formation is discussed along with space relations of vein quartz and ore.

The source of the quartz is considered, and fundamental questions of origin are raised.

PROPOSED FIELD CONFERENCE FOR 1954: BAKER, OREGON, TO RAPID CITY, SOUTH DAKOTA

T. C. Hiestand

Cities Service Oil Company, P. O. Box 139, Casper, Wyo.

Proposal of this conference has been discussed briefly with William W. Rubey (President G. S. A., 1950) H. D. Thomas (Chairman Rocky Mountain Section), and J. Hoover Mackin (Chairman Cordilleran Section). Possibilities of joint action of the three organizations await necessary official adoption.

Area of traverse lies generally between the meridian on the west, 118° 30′, on the east, 103°; also the parallel on the north, 45°, and on the south, 43° 30′. Progressing eastward from the vicinity of Baker to Rapid City, the caravan will have crossed the Cordilleran geosynclinal belt, the Idaho batholith, the Rocky Mountain belt, and on to the stable shelf of the Great Plains.

Organization of key personnel for the conference can be established through joint action for a trip about 1954, guided by a general chairman to be duly appointed. Proponent envisages advantages to both the Cordilleran and the Rocky Mountain Sections, with no loss of identity or purpose of either, in terms of a major research symposium.

The chief principle the proponent emphasizes for such conference is to make secure the broad avenue of geology into which converge the specializations of stratigraphy, structure, minerals, hard rocks, sedimentation, paleontology, geomorphology, petroleum and natural gas, and mining and engineering. Parenthetically, the papers and road log to be contained in the guidebook would provide ample plans for an excursion at such time as the International Geological Congress delegates may visit the United States a few years hence.

STRATIGRAPHY OF THE PHOSPHORIA FORMATION, CENTENNIAL RANGE, SOUTHWESTERN MONTANA*

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The Phosphoria formation (Permian) was mapped in detail and its stratigraphy studied in the Centennial Range in Beaverhead County, Montana, and Clark County, Idaho. Five units of the Phosphoria were differentiated and designated in ascending order, the a, b, c, d, and e units. Lateral variations in the units are marked. A brief description of these units is as follows:

e. Chert grading upward into siltstone, locally mapped as e_1, chert, and e_2, siltstone. Thickness, about 70 feet.

d. Phosphate rock, oölitic, grading upward into black shale. Thickness, about 20 feet.

c. Fossiliferous limestone, locally with a conglomerate interbedded, overlain by sandstone containing rodlike concretions. Limestone locally mapped as c_1, sandstone as c_2. Thickness, about 80 feet.

b. Phosphate rock, pisolitic hard; some quartzite interbedded. Thickness, about 0–15 feet.

a. Limestone and pyritiferous calcareous siltstone. Thickness, about 30 feet.

DISTRIBUTION OF URANIUM DEPOSITS IN THE UNITED STATES*

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Uranium deposits in the United States may be grouped as: (1) deposits with structural control, and (2) deposits with stratigraphic control. The deposits with structural control include veins, breccias, and pipes; disseminated deposits associated with fractures; pyrometasomatic deposits; and pegmatites. The deposits with stratigraphic control include (1) phosphates, carbonaceous shales, and lignites; (2) limestone and dolomite, (3) deposits of the carnotite type; and (4) surficial or caliche deposits.

Most of the known uranium deposits are in the western United States. Arizona, Utah, and Colorado contain the largest number of deposits.

The deposits with structural control, except the uraniferous pegmatites, are commonly in or related to igneous rocks of post-Cretaceous age, and many of them are Tertiary volcanic rocks. Notably few deposits are genetically related to Precambrian rocks and to Jurassic intrusives. The pegmatite deposits of the western United States are believed to be Precambrian; those of the eastern United States are post-Devonian.

Carbonaceous shales, phosphates, and lignites are restricted, for the most part, to terranes of Paleozoic and Tertiary age. Most of the carnotite-type deposits are in sedimentary rocks of Mesozoic age, and the most productive deposits are in rocks of Jurassic age.

Study of the distribution of known deposits indicated that the principal favorable areas for further prospecting are those in or near Triassic and Jurassic sedimentary rocks and Tertiary igneous rocks.

PITCHBLENDE DEPOSITS IN THE UNITED STATES*

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Pitchblende is found in the United States in (1) veins and breccia zones, (2) pyrometasomatic deposits, (3) pegmatites, and (4) sedimentary rocks. On the basis of past production, the deposits in veins and breccia zones are of the greatest commercial significance.

Most of the vein deposits containing pitchblende are in the Front Range mineral belt of Colorado,

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** Geologists, U. S. Geological Survey.

but a few are in Arizona, Idaho, Montana, Nevada, and Utah. The pitchblende deposits in the Front Range mineral belt appear to be coextensive with alkali-rich Tertiary intrusive rocks, but a similar relation is not known elsewhere in the United States.

Pitchblende-bearing vein deposits can be classified on the basis of mineral association as (1) quartz-sulphide type, (2) quartz-sulphide-carbonate type, (3) quartz-sulphide-carbonate-hematite type and (4) fluorite-quartz type.

Pitchblende is finely disseminated in deposits of the fluorite-quartz type. In mesothermal veins, pitchblende occurs as pods and stringers distributed erratically over relatively narrow vertical limits. In many deposits, pitchblende occurs both as hard botryoidal masses and as powdery films and coatings.

The metallic minerals commonly associated with pitchblende in vein deposits include galena, sphalerite, chalcopyrite, pyrite, silver minerals, and gold. In contrast to well-known deposits in Canada and Africa, cobalt or nickel minerals have been found in only a few of the domestic pitchblende-bearing veins. In a few places, veins containing secondary uranium minerals near the surface contain pitchblende at depth.

The relationship of pitchblende-bearing veins to types of wall-rock alteration has not been clearly established.

SECONDARY ENRICHMENT IN BOLIVIAN TUNGSTEN DEPOSITS

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The paper summarizes the writer's observations and conclusions on nature and extent of secondary enrichment in tungsten ore deposits of Bolivia.

During the writer's 14 years of mining practice in that country, he has examined or mined more than 28 tungsten deposits scattered throughout the Bolivian High Plateau and its foothills. Nine of these deposits, the most characteristic ones, are described.

Chemistry of tungsten is briefly reviewed, largely on the basis of Russian and Austrian literatures.

Tungsten minerals are discussed with the stress laid on their lesser-known peculiarities. One new mineral, farallonite, is described for the first time. Possibilities of existence of various, still unknown, tungsten minerals are pointed out.

As an aid in visualization of secondary-enrichment schemes several mineral-evolution charts have been worked out. These are introduced in this paper.

Deductions made in the theoretical part of the paper have been carefully checked in actual mine development and exploitation. The writer's access to old records and reports has made it possible for him to narrow the evaluation limits of the time factor involved in secondary enrichment.

Practical applications of the writer's investigation are twofold: (1) Additional ore tonnage produced on basis of his work were considerable, (2) a method could be devised to induce and to speed up artificially the processes of secondary enrichment.

Although the writer's knowledge of our domestic tungsten deposits is slight, he believes he has identified effect of similar processes in several instances in Colorado and Idaho.

GEOLOGY OF A PRECAMBRIAN AREA NEAR ROCHFORD, SOUTH DAKOTA

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Many parallels can be drawn between the geology of the Lead District of South Dakota and that of the Rochford area. The stratigraphic sequence of formations as determined at Lead can be applied successfully to the Rochford area.

This paper deals essentially with three formations: the Ellison, the Poorman, and the Homestake. The cummingtonite-bearing zone of the Homestake formation is a traceable but discontinuous horizon which necessitates close attention to significant changes in lithology across strike to maintain position in the stratigraphic sequence.

Petrological studies with both hand specimens and thin sections have been made in the attempt to provide a more firm basis for differentiation of the formations involved. The megascopic study

of outcrops within a single formation would suggest a considerable petrological variation, but microscopic analyses of thin sections reveals surprising uniformity of mineral content. One significant factor noted was the relative abundance of the various minerals present.

Extremely tight isoclinal folds typify the area examined. The formations strike slightly west of north with an average dip of 70°. The Homestake on outcrop is often a highly crinkled schist, whereas the Poorman and the Ellison exhibit less evidence of deformation. Probable evidence of cross folding is indicated in thin section.

SPACE-TIME CONCEPT IN GEOLOGY

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Geologists tend to neglect or minimize the components of space and the elements of time during decipherment of geological phenomena. The space-time concept should be critically adhered to in all stratigraphic, biostratigraphic, sedimentational, tectonic, geomorphic, and petrographic studies. To visualize in three dimensions and think in four dimensions is of prime importance to every geologist and engineer.

PATHOLOGICAL VERTEBRATES FROM SOUTH DAKOTA

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The fossilized remains of animals showing pathologic conditions are found in most fossil faunas. Fractures and arthritic conditions are the most commonly preserved evidences of illness among fossil animals.

A typical example of the arthritic condition is seen in a recently collected skeleton of a large brontothere from the Chadronian of South Dakota. This animal had an extreme case of *Spondylitis deformans* which tightly fused the first five thoracic vertebrae by the ossification of the ligaments. The intravertebral articular surfaces are not affected, but the vertebrae are firmly ankylosed, indicating that this condition was one of long standing before the death of the animal.

Two mammals in the Museum of Geology at the South Dakota School of Mines and Technology show nonfatal head injuries that were most likely received in fights. The best known of these is the type skull of *Nimravus bumpensis* Scott and Jepsen (1936) from the Whitneyan of South Dakota. This skull has been pierced through the left frontal and bears a partially healed wound, well surrounded by callous tissue and showing no sign of infection. All the evidence points to the fact that this wound was probably inflicted by the saber-toothed cat, *Eusmilus*, although it cannot be used as evidence either for or against the stabbing hypothesis with regard to the use of the canines by the saber-toothed cats.

A skull of *Mammuthus imperator* from Mina, South Dakota also has a healed wound in the frontoparietal region. This wound takes the form of a large saucerlike depression with a rough development of callous tissue in the center. This wound presumably resulted from a fight with another mammoth.

"REVERSE DRAG" ON HIGH-ANGLE FAULTS IN OAK CREEK CANYON, ARIZONA

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Oak Creek Canyon, south of Flagstaff, Arizona, is excavated along a north-trending, normal to vertical, Cenozoic fault. The fault is of interest because adjacent strata are bent contrary to normal drag relations. Upthrown strata bend upward, and downthrown strata dip down as the fault is approached. Bending is most pronounced where the fault changes trend and may affect strata on both sides, one side only, or be absent.

Contrary bending is not uncommon in the Colorado Plateau and has been reported elsewhere. Genetic hypotheses include:

(1) Breaking of an initial monocline by a fault of reversed throw (Hurricane, Muav Canyon faults)
(2) Sagging of strata by removal of basalt mass at depth (Hurricane fault)
(3) Elastic rebounding of strata beyond the point of equilibrium (Lulling fault)
(4) Compressional buckling following high-angle faulting (East boundary fault of Connecticut Lowland)
(5) Differential movements with initial throw later reversed (Gallup-Zuni Basin faults)

It is doubtful if one hypothesis will explain all cases.

Applied to the Oak Creek fault, monoclinal and rebound hypotheses are inadequate; each would create bending along the entire length of the fault. Sagging could not cause upbending. Compressional buckling would be as apt to form similar bending adjacent to the fault on both sides as opposing up-and-down bending. Differential movement is the most probable hypothesis. Normal drag was initially established. Later movements reversed original throw; dragged strata, however, retained their original attitude because of the "lubricating" action of a broad crush zone formed during initial displacement.

TERTIARY STRATIGRAPHY OF SOUTHEASTERN WYOMING AND NORTHEASTERN COLORADO

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Tertiary sediments in extreme southeastern Wyoming and northeastern Colorado were mapped. The sediments were dated on the basis of fossil vertebrates and grass seeds as Orellan (middle Oligocene) and Clarendonian (early Pliocene). They are equivalent to the Brule and the Ash Hollow formations of Nebraska.

In the Ash Hollow (Clarendonian) of southeastern Wyoming and adjacent Colorado are widespread pyroclast-bearing conglomerates. Petrographic analyses of these pyroclastic rocks relate them to rhyolites of Specimen Mountain, Colorado.

The abundance of volcanic rocks in the Ash Hollow, and their absence in the middle Miocene rocks immediately to the north indicate either late Miocene or early Pliocene for the inception of volcanism in the Front Range of Colorado.

Drainage during the deposition of the Ash Hollow, as determined by the study of the orientation of discoidal pebbles, was from the direction of the Front Range, Colorado.

The gangplank surface east of the Laramie Range is formed on conglomerates of the Ash Hollow formation.

GEOLOGY OF THE APEX STOCK, GILPIN COUNTY, COLORADO

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The Apex stock is near the center of the northeasterly trending belt of Tertiary (?) intrusions that cuts diagonally across the Front Range of Colorado. The stock intrudes the schists and gneisses of the Precambrian Idaho Springs formation and is about 4 miles long and a mile wide. The longer dimension is approximately parallel to the regional structure of the Precambrian rocks, but it is thought that this relationship is fortuitous. Field evidence supports the hypothesis that the stock was localized by extensive fault and shear zones cutting the older rocks.

Study of faults exposed in mine workings and elsewhere suggests faulting both prior to and subsequent to the intrusion of the stock. Regional studies indicate that the faulting is Laramide.

The stock probably came from a deep source of relatively homogeneous monzonitic magma, but extensive contamination by stoped blocks and pervasive deuteric stage albitization have obscured and, in places, obliterated the original texture of the rock, making accurate classification difficult.

Petrographic studies and field observations support the conclusion that the stock is apically truncated.

TERTIARY STRATIGRAPHY OF THE RATTLESNAKE HILLS, CENTRAL WYOMING

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In the Rattlesnake Hills of central Wyoming are some 25 ancient volcanoes. Debris from these volcanoes is found in various Tertiary units immediately to the west. The object of this investigation was to determine the age and relationships of the Tertiary rocks and thus to date the periods of volcanic activity in the Rattlesnake Hills.

Five Tertiary units were recognized in the area:

(1) A Bridgerian (middle Eocene) unit, consisting of varicolored sandstone and green clays, dated by means of a fossil flora.

(2) A late Bridgerian or early Uintan (late Eocene) unit, consisting of conglomerates, clays, sandsandstones, and tuffs, dated by means of a vertebrate fauna.

(3) A Chadronian (early Oligocene) unit consisting of buff to white ashes, clays, and conglomerates. A vertebrate fauna from these rocks indicates a very early Chadronian age.

(4) A Hemingfordian (early middle Miocene) unit of buff concretionary sandstone, dated by means of a vertebrate fauna.

The conclusion is that there were two phases of volcanism in the Rattlesnake Hills. The first phase was active throughout most of Bridgerian and Uintan (?) time. The second phase of volcanism was active throughout all of Chadronian time.

EVIDENCE BEARING ON THE CONSANGUINITY OF MISSOURI AND OKLAHOMA PRECAMBRIAN IGNEOUS ROCKS

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Petrologic, petrographic, and chemical data point to consanguinity of the Missouri and Oklahoma Precambrian igneous rocks. The sequence of geologic events may be interpreted as very nearly the same, and the mode of occurrence of granophyric and other intrusive bodies is thought to be identical.

The essential and accessory minerals in the granites and gabbros, and probably the minerals in the extrusive acidic volcanics and quartz basalt dikes common to both localities, are the same. In the granites, fluorite, apatite, sphene, epidote-zoisite, and zircon (normal type) constitute the nonmagnetic heavy accessory mineral suite. The percentage distributions of the accessory minerals vary with compositional changes in the essential minerals, notably with respect to the Ab-An ratio in plagioclase, and the femic mineral content. For petrographically identical rocks from both localities, the percentage distributions of the accessory minerals are essentially alike. Zircon is somewhat more abundant in the Oklahoma granites. The absence of tourmaline in both suites is conspicuous. The petrography of the diabases is the same.

Variation curves, after Larsen, which suggest petrogenetic consanguinity for rocks with widely different compositions within a petrogenetic province were constructed for the Missouri rocks. Analyses of Oklahoma rocks fall onto the same curve. A curve similarly compiled from analyses of Keweenawan rocks in Minnesota, Michigan, and Ontario is identical.

SIGNAL BUTTE IGNEOUS GROUP

E. H. Stevens

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Attention is called to an igneous group located in the Colorado Front Range about 47 miles south-southwest of Denver. The entire group lies within an area of less than 1 by 2 miles. All the rocks are monzonite porphyries or closely related rocks. The oldest is a volcanic neck making a hill called Signal Butte. It is 1300 feet high and rises about 300 feet above the crests of the neighboring ridges. It pre-dates the Lower Overland Mountain surface of middle Oligocene age. Extending in a line for about 2 miles to the north-northwest a younger series of intrusive and extrusive rocks ends

in a volcanic cone with the crater still well preserved. Surrounding the cone is a bed of tuff apparently on the Bergen Park surface of Miocene age. This is the lowest-developed surface in the area, and the tuff may be quite recent. Based on the amount of erosion of the cone and the tuff the latest volcanics here were probably contemporaneous with the South Park Quaternary volcanics, while the Signal Butte volcanic neck was probably contemporaneous with the Cripple Creek activity.

MARL FACIES OF THE LOWER PIERRE IN SOUTH-CENTRAL SOUTH DAKOTA*

Robert E. Stevenson

State Geological Survey, Vermillion, S. D.

The Crow Creek marl facies of the Sully member, which crops out along the Missouri River from De Grey, Hughes County, to southeast to Yankton, shows its greatest stratigraphic variation in Charles Mix and Gregory counties. Here it is thicker and at several localities has been separated into two marls by the Gregory clay.

Lithologically, it is a marl and chalky marl with scattered quartz grains and contains a *Gumbelina-Globigerina* microfauna. Locally, the basal 3 feet to 6 inches is a sandy marl.

The marl was deposited in a sublittoral environment of the Pierre sea at some distance from shore. The sand grains are believed to have been derived by wind and water from the middle Cretaceous sands exposed on the Sioux ridge.

SECONDARY URANIUM DEPOSITS IN THE UNITED STATES†

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Reconstituted, or secondary, uranium minerals found in domestic deposits include oxides, phosphates, silicates, vanadates, arsenates, sulfates, and carbonates. Next to the vanadates, carnotite, and tyuyamunite, the most abundant are the phosphates autunite and torbernite and the silicate uranophane. Less common are deposits containing the oxides gummite and pitchblende; the phosphates dumontite and uranocircite; the silicates kasolite, sklodowskite, and soddeite; the arsenates zeunerite and uranospinite; the sulfates zippeite, uraconite, and johannite; and the carbonates rutherfordine and schroeckingerite. Other secondary minerals, in general, are only of mineralogic interest.

Most secondary uranium mineral deposits show no apparent relation to known primary uranium minerals. The deposits now being mined at Marysvale, Utah, however, are surface expressions of pitchblende-bearing deposits. Recent studies indicate that development of secondary minerals has in some places resulted in concentration and elsewhere in dispersion of uranium. Concentrations from ground water have formed extensive deposits of schroeckingerite in Sweetwater County, Wyoming.

Many uranium compounds appear to be highly soluble and mobile. Successful distinction between secondary deposits resulting from concentration and those resulting from dispersion of primary deposits has not generally been made to date. Some sooty pitchblende is secondary.

GEOLOGY OF CENTRAL MIDDLE PARK, COLORADO

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The central area of Middle Park shows few of the open basins characteristic of the Colorado Parks. Northwest-trending hogback ridges give it a mountainous appearance. These ridges are associated with the major structure of the area, a northwest-plunging syncline. They are the resistant beds in the Middle Park formation and make continuous outcrops several miles long. Underlying this formation are Cretaceous and Jurassic sediments.

A fault parallels the west side of the syncline. This fault caused repetition of the basal Middle Park and upper Cretaceous strata.

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The Middle Park formation consists of a basal member of pyroclastic material, which outlines the syncline in a persistent ridge, and a thick succession of conglomerate, grit, sandstone, and shale with small amounts of pyroclastic material throughout. The formation is about 5000 feet thick.

Igneous rocks of three ages are exposed: Precambrian granite in Byers ridge southwest of the syncline; dikes in the Middle Park formation at the northern end of the area; and lava flows on and around Elk Mountain at the northern end of the syncline.

The Colorado River, a superimposed stream, flows at right angles to the synclinal ridges into which it has cut several water gaps and wind gaps.

FROST ACTION ON EXCAVATED SLOPES IN NIOBRARA CHALK, FORT RANDALL DAM, SOUTH DAKOTA

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Omaha District, Corps of Engineers, Omaha, Neb.

The combined effects of moisture and temperature variations associated with frost action seriously altered the wall of Cretaceous Niobrara chalk designed as four on one slopes around the excavation for the outlet works at Fort Randall Dam, on Missouri River in South Dakota.

In view of equally steep natural slopes which are stable in Niobrara chalk in the vicinity, it was anticipated that uniform 4 on 1 slopes, formed by vertical coal-saw cuts with set-back benches at 30- to 50-foot intervals, would be stable during the construction period. The chalk slopes thus formed during the spring and summer remained stable throughout the winter; however, spalling began the following spring when seasonal temperature raised sufficiently to promote thawing. Seasoning of the slopes, during the summer months, was not sufficient to provide a protective layer against direct exposure of pore moisture to freezing. Although the ultimate design required placement of concrete on some slopes and backfilling adjacent concrete walls on others, the uncontrolled spalling in the spring produced safety hazards during construction. Treatment of sections potentially hazardous to structural design was accomplished by pinning the spalling material to firm chalk with grouted anchor bars.

Future design, on permanent open-cut excavations, will feature 1 on 1 slopes as a measure of reducing the hazards developed by loose pieces of chalk. Temporary exposures of chalk, requiring concrete placement and backfilling, will follow the 4 on 1 pattern, however; specification will require that final concrete and backfill construction be accomplished prior to late fall and winter seasons.

MICROSCOPIC STUDY OF AN INCLUSION IN THE IDAHO BATHOLITH

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A large, unusually well preserved inclusion of Triassic (?) schist occurs in the granitic rock of the Idaho batholith near the junction of Carey Creek with the Salmon River approximately 15 miles east of Riggins, Idaho. The inclusion is some 7 miles east of the contact between the batholith and Triassic rocks and is at least 1500 feet vertically below the present erosion top of the intrusive.

Despite the deformation and metamorphism necessarily accompanying the emplacement of such a foreign body, it seems to have suffered few physical changes and resembles the Triassic host rock at the western batholith contact. The inclusion is sheathed in a thick coating of coarse, biotite mica that evidently formed an insulation from the surrounding magma and thus preserved it.

URANIUM IN FLUORITE DEPOSITS*

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The association of small quantities of fluorite with uranium minerals in veins has been reported for many localities. Recent studies in Colorado, Utah, Wyoming, and New Mexico indicate that uranium is a common constituent of many fluorite deposits.

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Fluorite deposits known to contain uranium occur in breccia zones, veins, pipes, and bedded replacement deposits. These deposits can be grouped on the basis of essential minerals as (1) fluorite, (2) fluorite-quartz-sulphide, and (3) fluorite-sulphide deposits. The deposits contain pitchblende or other primary minerals, together with such secondary uranium minerals as schroeckingerite, torbernite, autunite, uranophane, carnotite, and sklodowskite.

In some deposits the uranium is in fine-grained primary minerals disseminated through the fluorite ore body; in others the uranium is in the fluorite itself in a form not yet identified. Secondary uranium minerals coat fracture surfaces, grain boundaries, and vugs in both the ore bodies and the adjacent wall rocks.

Purple fluorite is commonly associated with radioactive deposits, but the many exceptions to this rule make this a criterion of limited value in prospecting for uraniferous fluorite deposits.

LOCALIZATION OF SODIUM SULFATE DEPOSITS IN NORTHEASTERN MONTANA AND NORTHWESTERN NORTH DAKOTA*

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The sodium sulfate deposits of northeastern Montana and northwestern North Dakota are confined to depressions within the glacial drift. The alignment of the deposits, many of which are linear, suggests some form of glacial control. It is believed that the localization of these deposits is related to buried ice-marginal channels.

Two types of channels are recognized. One type was formed during the withdrawal of the last ice. It is filled with sand and gravel and, insofar as known, contains no exploitable sodium sulfate deposits. The other type of channel was formed and floored with sediments during a temporary stillstand of the ice. These sediments were later buried beneath till of a renewed advance. In places, the till was thick enough to fill the former channels. Elsewhere, the till merely surfaced the channels. These elongate, till-surfaced swales and their concealed channel sediments trend irregularly across the area. Commercial deposits of sodium sulfate are in depressions within these swales. The alignment of the deposits resulted from their position within the till-surfaced channels.

It is thought that the buried channel sediments contain the sulfate-rich waters under artesian head, and that these waters locally escape upward into the depressions within the till-surfaced swales where evaporation causes concentration.

SOME URANIUM DEPOSITS IN SANDSTONE*

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The uranium deposits in sandstone of the Jurassic Morrison and Entrada formations of the Colorado Plateau are relatively well known and have long been the principal sources of domestic uranium and vanadium. Not so well known are uranium deposits in other sandstones that range from Paleozoic to Tertiary.

Of the uranium deposits in sandstone, some are of the Colorado Plateau type, but many others differ from this type in mineralogy, host rock, localization, and possible origin.

The deposits may be grouped on the basis of mineral or metal assemblage into (1) uranium-vanadium deposits; (2) copper-uranium-vanadium-carbonized wood deposits; (3) uraniferous asphalt deposits; and (4) carbonate deposits.

In general these deposits occur in lenses of argillaceous sandstone or conglomerate interbedded with shales. Common associated materials are iron oxide, carbon, and copper compounds. The localization of some of these deposits appears to be controlled by initial sedimentary features of the enclosing rock, that of others by porosity, fractures, and proximity to the surface. Some of the uranium minerals may have been deposited from ground water, some may have formed by weathering and oxidation of other minerals, and some may be hydrothermal in origin.

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ABSTRACTS OF PAPERS PRESENTED AT THE MEETING OF SECTION E, AAAS, IN PHILADELPHIA, PENNSYLVANIA, DECEMBER 27, 28, 1951

PETROLOGY AND STRUCTURE OF THE HEBRON GNEISS, CONNECTICUT

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The Hebron gneiss formation of eastern Connecticut presents an interesting relationship between petrologic units and structural trends.

The area is composed of highly granitized gneiss to the east and less granitized gneiss near Bolton Notch approximately 10 miles to the west.

The structural trends of the gneiss layers and bands vary from strong east-west to north-south as they are followed from east to west in this area.

Available field evidence indicates that: (1) structural units and petrologic units do not coincide; (2) the structures of the western portion of this area may provide a key to pre-Triassic movement in the Eastern Upland metamorphics of Connecticut.

NEW OIL DEVELOPMENTS IN MEXICO IN RELATION TO THEIR REGIONAL SETTING

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Petroleos Mexicanos has located and developed several oil and gas fields in the Burgos Basin, recently redefined as the southwest extreme of the Gulf Coast geosyncline; such fields are located in off-shore bars caught in shoals developed in the so-called flexures where brackish and marine sediments interfinger.

In the Tampico-Tuxpan region, a field was located and developed about 5 miles west of the famous Golden Gate; that field appears to be a biostrome developed on a basement complex high in the Tamaulipas shelf.

In the western part of the Macuspana-Campeche Basin a new field was discovered which promises not only important reserves, but opens great possibilities to this basin.

GEOGRAPHIC WORK OF ARNOLD GUYOT

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Arnold Guyot is interpreted as the foremost American geographer of the nineteenth century. Recent investigation has uncovered a large number of Guyot's geographic works as well as references to others which have not been noted previously by students of the history of geography—notably: *Heights of North Carolina Mountains* (1857), *Measurement of the mountains of western North Carolina* (1860), *Manual of Geographic Teaching* (1870), *Physical Geography* (1873).

In addition to his contribution to glaciology and meteorology, Guyot greatly extended the westward limit of hypsometric mapping in the United States. He determined the heights and toponomy of peaks and valleys throughout the Appalachian mountain system and elsewhere. These data and maps served as bases both for military maps used in the War between the States and for later topographic sheets. Many of the names given to peaks by Guyot still survive. Four mountain peaks in the United States named for Guyot attest to his high standing among mountaineers.

He directed the preparation of several of the earliest sets of atlases and wall maps on which major differences in relief were shown by color, green for lowlands and shades of brown for uplands, a system still used. He indicated variation in steepness of slope by width of hatching, and included compara-

tive landform profiles with each map. These maps are remarkable for both their innovations and attention to detail. Thus, in view of his contributions, Guyot merits considerably more recognition than he has been accorded by modern geographers.

GEOLOGICAL CONDITIONS OF OIL OCCURRENCE IN MIDDLE EAST FIELDS

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(1) The Middle East geological provinces are: (i) The Arabo-Nubian and Arabo-Somali massifs of Precambrian igneous and metamorphic rocks in Western and Southern Arabia; (ii) The foreland shelf, north and east of the massifs; (iii) The orogenetic Taurus-Zagros-Oman Mountain belt, peripheral to the foreland.

Interpretations of the tectonics are controversial; some authors emphasize the possible role of taphrogenesis and vertical movements in the basement, while others postulate a long history of intermittent compression (Alpine orogenies) from the north and northeast.

All commercial oil so far discovered occurs in anticlinal traps in provinces (ii) and (iii), though the possible existence of other types of accumulation is not excluded.

(2) The sedimentational history of the region was conditioned by slow, progressive subsidence of the Arabian foreland, interrupted intermittently by epeirogenetic uplift movements which are reflected in thickness and facies variations of the sediments.

Deposits of successive marine cycles tongue into a flange of continental sands surrounding the Arabo-Nubian and Arabo-Somali massifs.

Excluding the nonproductive pre-Mesozoic and post-Miocene rocks, the stratigraphy of the oilfield belt consists of: (i) Triassic to Lower Cretaceous—Mainly chemical limestone/dolomite deposition; prolific oil producer in Easten Arabia; (ii) Middle Cretaceous—(a) Nummulitic limestone, chalk, and marl, with oil in reef limestone complexes and in fractured limestone in north Iraq; southwest Iran; southeast Turkey. (b) Sands and shales from Western shore lines. Prolific production in Bahrein, Kuwait, Basrah; (iii) Miocene—Rapidly alternating evaporites, limestones, and clastics; major oil pools in southwest Iran and Iraq.

Fracturing and availability of plastic or unfractured cover are important factors in the migration and accumulation of Middle East oil.

GRAPHS FOR VISUAL COMPARISON OF SEVERAL FACTORS IN HEAT EXCHANGE NEAR BARROW, ALASKA*

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From October 1949 to November 1950, during a project sponsored by the Office of Naval Research and the Geological Survey at the Arctic Research Laboratory near Barrow, Alaska, data were collected on several factors in heat exchange between the earth and atmosphere. The data include: near-surface ground temperatures at intervals of 2 days; continuous under-snow temperatures; density, porosity, and thickness of snow at periodic intervals; continuous air temperatures; and continuous under-turf temperatures during the summer. Supplementary data were obtained from near-by stations: measurements of continuous wind velocities and average wind directions from the CAA, half a mile distant; solar-radiation data from the U. S. Navy, half a mile distant; and data for continuous air temperatures, per cent of cloudiness, daily precipitation, and per cent of humidity from the U. S. Weather Bureau, 4 miles distant.

For visual comparison of these data the following graphs were prepared: an isogram with ½° C isotherms of ground temperatures from the surface to a depth of 48 inches (including the active layer,

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15 inches thick) in continuous permafrost; and curvilinear graphs of solar radiation, wind velocities, snow thicknesses, air temperatures, cloudiness, humidity, and under-snow temperatures. Histograms of snow densities and porosities are superimposed on the graphs. Wind directions are shown by arrows.

These graphs show clearly the procession of seasons at and near the ground surface. Cumulative effects of all factors, and effects of some individual factors upon ground temperatures, are distinguishable. Ground temperatures demonstrate that the active layer also freezes upward from its base by loss of heat into the permafrost.

GEOGENIC JERSEY

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If I were to invent a word to describe the geographic features of New Jersey, it would be the word "geogenic." A person who usually looks attractive in photographs is said to be photogenic. Is it not reasonable to say that a region that looks attractive in geography is "geogenic"? Within the borders of this one small State are samples of a surprising variety of geographic environments. The map and photographs with this article show us that within a few hours ride from the center of the State it is possible for one to visit sea shore or mountain; sparsely populated townships or one of the most crowded regions in the world; one may visit farms, mines, great factories, huge warehouses, or historic shrines. Many States have large areas of greater geographic specialization, but few have as many different geographic features within such convenient travel distances of each other.

JAMES RIVER SYNCLINORIUM AND RELATED STRUCTURES IN THE WESTERN VIRGINIA PIEDMONT*

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The James River synclinorium in Virginia is marked by a narrow belt of rocks of relatively low metamorphic grade, lying just southeast of the Blue Ridge anticlinorium and extending from Orange County to the North Carolina line near Stuart in Henry County, a distance of 200 miles. The central part of this belt was formerly mapped as an anticlinorium (Furcron, 1935), but detailed study has shown the structure to be synclinal and the sequence of formations to be the reverse of that originally postulated. Units mapped include, from old to young, Candler phyllite and schist, Joshua schist, Arch marble, Pelier schist, Mount Athos quartzite and marble, and Slippery Creek greenstone volcanics.

Generally along the western border of the synclinorium, Candler phyllite lies upon Lynchburg gneiss or upon greenstones which occur near or at the contact between these formations. These greenstones are partly or wholly correlative with the Catoctin. Where Lynchburg gneiss is exposed on the southeast side of the synclinorium, at the Sherwill anticline northeast of Altavista, the sequence Lynchburg, greenstone, Candler is repeated.

Jonas (1932) considered Candler phyllite to be a retrograde phyllonite, separated from Lynchburg gneiss by the Martic overthrust. Evidence indicates, however, that the Candler is not generally retrograde, and the repeated sequence Lynchburg, greenstone, Candler opposes the existence here of a major thrust. Within the synclinorium, folding is chiefly isoclinal, and thrust faults have produced an imbricate structure.

The narrow width and great length of the belt of younger rocks preserved in the James River synclinorium suggest that the structure is a tight, deep infold. Perhaps these rocks are somewhat comparable to the *Schistes lustrés* of the Alps, and the overall structure represents the beginning of nappe structure which never advanced to the stage of major thrusting.

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PRESERVATION OF THE TEXTURE OF ECHINODERM PLATES IN METAMORPHOSED ROCKS

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Typical examples of the characteristic cribriform texture of echinoderm plates, especially of cystoids and Paleozoic asteroids and echinoids, will be shown. Two examples from the crystalline rocks of New York State show that this texture has survived moderate metamorphism. Proof of the presence of such remains can be of considerable importance for the stratigraphic interpretation of metamorphic terranes.

HUMISOL

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The term "humisol" is here introduced as a collective name for two soil families, podzols and latosols, formerly held to be separate. The complex soil-forming process resulting in the humisol is fundamentally a decomposition of the aluminosilicates and ferro-aluminosilicates into the various stable forms of silica, alumina, and iron, followed by a removal of alumina and iron into the lower horizons of the soil profile. Like most other chemical reactions, the rate of the reactions here involved is modified by temperatures. The extent of its completeness is determined by time and by a number of subordinate variables, including the pH levels. What was formerly believed to be a latosol is, more often than not, a truncated podzol of considerable pedologic-chronologic age—a mature or senile podzol, a humisol. A podzol is, in reality, a well-preserved juvenile to mature humisol.

This interpretation is based on morphological and chemical studies of soils of the Atlantic Coastal Plain, from Maine to Florida, and elsewhere. The errors of the podzol-latosol misconceptions were due to the following kinds of neglect, on the part of several generations of pedologists: (1) uncritical and inadequate pH data; (2) nonrecognition of the effects of man's agriculture on soil-profile characteristics; (3) ignorance of the time factor in the soil equations, with the consequent dogma of very rapid pedogenesis; (4) the dogma of "equilibrium" derived from regions of low-rainfall penetration and applied to regions of high-rainfall penetration; (5) inexperience in the recognition of ancient weathering surfaces, of the palaeosol, and of other relics of old pedogenesis; (6) nonappreciation of the geomorphologic aspects of pedogenesis.

The fundamental unity of the soil-forming process does not preclude its local and regional modifications, depending on kinds and proportions of the reagents, the reaction rates, the time-temperature factors, effects of man, and others. We believe nevertheless that the philosophical basis of pedology here developed helps to clarify a large number of great and small problems in the somewhat sterile modern pedology.

GROUND-WATER PROBLEMS IN PENNSYLVANIA

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Although Pennsylvania's overall supply of ground water is adequate for most present and estimated future needs, serious ground-water problems exist in some heavily populated and industrialized locations. Such problems are largely the result of inadequate hydrologic information, unwise engineering planning, and indifference to practices that result in water pollution.

Ground-water studies in Pennsylvania are being conducted co-operatively by the Pennsylvania

Topographic and Geologic Survey and the United States Geological Survey. These studies include ground-water inventories by counties and a statewide network of water-level observation wells for measuring changes in ground-water storage. It is estimated that some 500 million gallons of ground water are pumped daily for municipal, industrial, and rural requirements in Pennsylvania.

Large withdrawals for air-conditioning use in Pittsburgh have caused ground-water levels in parts of the Golden Triangle area to decline so much that little additional development appears possible. However, large potential supplies occur in near-by valley deposits along the Allegheny and Ohio rivers.

In the south part of Philadelphia heavy ground-water pumpage has induced movement of chemically inferior waters into the principal aquifer. The concentration of dissolved minerals has increased so greatly in recent years that continued use of ground water by south Philadelphia's industries and by the United States Naval Base is seriously threatened.

Extensive supplies of undeveloped ground water are present in the Commonwealth, chiefly in glaciated areas and in valley deposits of streams that once carried glacial meltwater. Additional research is required to define adequately these and other areas of future ground-water supply.

GLACIAL WATERS IN CATSKILL (NEW YORK) AREA

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Discrepancies in published writings (Woodworth, Fairchild, Brigham, Stoller, Chadwick, Cook) as to the manner of ice dissipation and its accompanying obstructed drainage in the area of "The Catskills" (which includes, besides the central mountain mass, also Helderbergs, Shawangunks, and margining Hudson and Mohawk valleys) are ironed out by more penetrating study (such as the writer's Glens Falls paper in 1928) and the way opened for field review by graduate students. The road to solution of several major problems is explored.

PETROLEUM EXPLORATION AND DEVELOPMENT IN FRANCE, 1950 AND 1951

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Both 1950 and 1951 have been marked by considerable development in the efficiency of petroleum exploration in continental France. A start has been made in the study of unexplored, or partially explored, sedimentary basins, as follows: Alsace Valley where, in addition to the old Pechelbronn field, 105,000 acres of new land have been leased and a new Company created; Valley of the Saone, Jura, Savoie, and Provence, where 3,243,000 acres are under exploration by the same company which operates St. Marcet gas field, in the south of France; Paris basin, where geological work has started; Lower Valley of the Rhone (Camargeu), intensely drilled; and 4,356,000 acres of land, in the northern part of the Aquitaine basin, granted to the French Standard Oil.

The outstanding event was the discovery of Lacq oil field, near the town of Pau, in December 1949, that has yielded, up to July 1, 1951, about 1,150,000 barrels of paraffinic oil, of mixed base type, 21.5° API, with 14 producers and 11 wet. Production in St. Marcet gas field is steadily increasing: during 1950, 6,630 million cu. ft. of gas and 2,220,000 barrels of condensate. In the Pechelbronn oil field, production increased by more than 30 per cent, following discovery of oil in the deep Triassic beds of the Rhine valley; yearly production averages 450,000 barrels. French works and results, in 1948, 1949, 1950, and the first six months of 1951 are summarized; these results have been obtained with 40 rigs, half of which have a drilling capacity over 8000 feet.

PETROLEUM PROSPECTS OF DENMARK

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Denmark lies on the northeast side of the northwest German sedimentary basin. This basin embraces the whole of Denmark, Pomerania, northwest Germany, the low countries, the North Sea, and a part of England. Denmark's position in the basin in relation to that of northwest Germany, particularly to the oil-productive regions of that country, is discussed. The sedimentary rock units laid down in this basin in Denmark, with minor exceptions, are remarkably similar to those laid down elsewhere in the basin. The similarity in the regional geologic setting of Denmark and close similarity in the stratigraphy to that of the productive regions of northwest Germany are the principal reasons for optimism in regard to petroleum prospects in Denmark. Eastern Denmark lies on the northeast margin of the basin, the productive Emsland area of Germany on the southern margin. The margins in each instance are flanked by major piercement salt-dome provinces. The principal productive horizons of Germany are represented in Denmark and occur in somewhat similar lithologic facies. From the regional geologic standpoint, Denmark thus occupies a position similar to that of northwest Germany where production has been found not only in the marginal zone of the basin but within the piercement salt-dome province as well.

RIPALTA FIELD, A TYPICAL GAS FIELD OF PO VALLEY, NORTHERN ITALY

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After a brief résumé of hydrocarbon research in northern Italy, the author summarizes the stratigraphic and structural conditions of the Po Valley, on the basis of studies carried out by A.G.I.P. The Po Valley is partly a great sedimentary basin filled by a thick series of terrigenous Tertiary and Quaternary sediments; the Pliocenic formations are folded in very long anticlines and transgressively covered by Pliocenic clays and by Quaternary sands and clays. On the above-mentioned anticlines are developed secondary culminations, where the more important gas accumulations are located, among them the Ripalta gas field.

The Ripalta structure was discovered by A.G.I.P. by reflection seismic survey in 1940–1941; but the first wildcat was not started until 1947. At present 19 wells are completed, of which 16 are producers and 3 are dry holes. Gas is from sands of the lower Pliocene on the crest of the structure at a depth of 1353 meters. The producing sandy horizons are covered by clays of middle and upper Pliocene and Quaternary age. The wells on the top of the structure have about 80 meters of sandy formation containing about 30 meters of pay section. Average daily production per well is 4,200,000 cu. ft. through ¼-inch choke with casing pressure 2200 p.s.i. and tubing pressure 2100 p.s.i.

The author gives a detailed description of the stratigraphy and the general conditions of sedimentation and accumulation.

DATING THE WISSAHICKON SCHIST AT PHILADELPHIA, PENNSYLVANIA

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Previous workers in the Wissahickon schist have been divided into two camps—those who believe the Wissahickon schist is Precambrian, and those who would assign the formation to the lower Paleozoic. Most recent work, together with similar correlation problems in other areas, suggests strongly that the Wissahickon schist at Philadelphia is a higher-grade metamorphic equivalent of phyllitic rocks lying to the northwest. The phyllite, in normal stratigraphic sequence with other Paleozoic rocks, is Cambro-Ordovician or possibly Cambrian. In the light of recent work many objections to the assignment of the Wissahickon schist to the Paleozoic no longer seem valid.

STRATIGRAPHY AND STRUCTURE OF GEORGIA CRYSTALLINE ROCKS

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Earlier Precambrian, represented by metasedimentary schists and gneisses, migmatites, "augen" gneisses, hornblende and diorite gneiss, is exposed east of Nacoochee fault; remnants of Late Precambrian series overlie it locally to Fall Belt.

Late Precambrian Series: Quartzite, conglomerate, biotite gneisses, mica schists, pseudodiorite, hornblende gneisses, etc; occurs from Cartersville fault eastward; a five-fold classification is suggested; its composition and stratigraphy indicate source of sediments from west and northwest; occurs in large complex folds and synclinoria, broken by overthrusts; a synclinorium involving youngest member composes high Blue Ridge area west of Nacoochee thrust, and a "middle" member of the Ducktown Basin syncline.

Latest Precambrian (?) (1) Muscovite-graphite schists, staurolite schists, marbles, or Murphy syncline and its extension southwest of Allatoona; (2) similar rocks of Brevard syncline, which overlie Earlier and Late Precambrian.

Paleozoic (?): Southwest extension of Carolina Slate Belt (Little River series of G. W. Crickmay), exposed near Fall Belt, extending under Coastal Plain; shales, slates, phyllites, volcanics, altered to mica schists near later granites; exposed with low dips, overlying Precambrian.

Metasedimentary sequences are broken by overthrusts which rotate in strike from north-south alignment of Cartersville thrust of crystallines over Paleozoic slates and limestones to almost east-west alignment of Goat Rock Dam thrust near Fall Belt. Brevard and thrusts northwest of it override pelitic members of Late and Latest (?) Precambrian series; Brevard and more southerly thrusts are marked by extensive granite mylonites.

Preliminary age classification of granites is suggested, based upon above classification of metasediments. Large intrusions do not occur west of Nacoochee fault, but aplites and pegmatites occur locally; also, granitization east of Cartersville and Chatsworth. Younger granites occur east of Brevard thrust where they extensively intrude Little River series.

SIZE AND SORTING IN SEDIMENTS

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Continued investigation into the relationship between average grain size (phi median) and sorting (phi percentile deviation) indicates that the majority of sediments follow definite curvilinear trends and may be characterized as follows:

(1) Aqueous sediments fall on a trend possessing two maxima of poorest sorting around average sizes (medians) of 6.5–7.0 ϕ (11–7.8 microns) and $-5\ \phi$ (32 millimeters) respectively. Best-sorted sediments occur at minima of 2.5 ϕ (177 microns) and 10–11 ϕ (1–.5 microns). A third minimum beyond $-5\ \phi$ appears likely.

(2) Aeolian sediments show a more restricted but similar trend translated toward finer sizes and better sorting. The maxima of poorest sorting occur around 6ϕ (15.6 microns) and 1.5ϕ (350 microns). A well-defined minimum (best-sorted sediment) can be found around 3ϕ (125 microns), and a second is tentatively suggested.

(3) A possible trend of approximately similar form is displaced from the aqueous trend toward coarser sizes and poorer sorting. It may represent immature sediments deposited after short-distance aqueous transport and/or gravitationally deposited material.

The curvilinear trend for aqueous sediments may be subdivided into at least two "populations" reflecting suspension and traction sedimentation. The aeolian trend may also be subdivided into suspension and saltation populations although neither appears to be as complete as for aqueous sediments.

By plotting median and phi percentile deviation for a representative set of sediments it appears possible to predict the agency and manner of deposition for the majority of sediments.

ORIGIN OF SOME PLUTONIC GRANITIC GNEISSES IN THE NORTHERN AND SOUTHERN APPALACHIANS*

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Two types of plutonic granitic gneiss that are widespread in the western parts of New Hampshire, Massachusetts, and North Carolina differ in their tectonic relations. These differences are discussed with reference to the significance of their tectonic relations and to the question of their origin by granitization. One type, exemplified by the Oliverian plutons of Billings, is petrographically complex, appears in concordant, domical, or anticlinal bodies as much as 27 miles long, and shows much evidence of both static and kinematic granitization. The other type, exemplified by the Bethlehem gneiss of western New Hampshire, occurs as semiconcordant, lenslike bodies, some 50 or more miles long, with equally heterogeneous composition. The Bethlehem type shows little evidence of granitization in place; but some features point to an origin by granitization at greater depths. Both types of gneiss are essentially syntectonic and have had complex histories of formation and movement during Paleozoic orogeny.

As a means of evaluating evidence for and against granitization in these bodies, hypothetical features of granitic gneisses of metasomatic origin are discussed and compared with characteristic features of the two types of plutons.

It is concluded that, in large part, the Oliverian plutons are products of kinematic granitization in anticlinal structures that prevented their movement independently of the enclosing rocks. The Bethlehem type of plutons, on the other hand, may have originated by similar processes in synclinal structures and moved, as "tectrusive" bodies, considerable distances from their sources.

GEOLOGY OF COASTAL ECUADOR WITH REFERENCE TO PETROLEUM DEPOSITS

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Ecuador's northern boundary with Colombia is approximately 500 miles south of the Panama Canal; the coast line extends to the Peruvian border, some 400 miles farther south. The topography of this area varies from a series of mangrove swamps to abrupt ranges of hills. Both structural and climatic conditions have had great effect on the relief. Recent erosion is considerable.

Sediments consist of Upper Cretaceous, Tertiary, and Recent deposits; Tertiary is the thickest, totalling over 50,000 feet, and ranging from Middle Eocene to Upper Miocene. Tertiary is predominantly marine and composed of sands, sandstones, shales, and occasional limestone beds. The Cretaceous is largely limestones, cherts, and reworked volcanics. Although both Cretaceous and Tertiary are present on both sides of the Andes Mountains, these periods have no counterparts in these areas insofar as depositional history is concerned. There are a few localized volcanic intrusions.

The structure of the coastal area of Ecuador consists of a series of positive and negative areas, the latter being adjacent to the coast line. Three sedimentary basins are: Progress Basin in the southern portion, the Jipijapa-Quininda Basin in the central portion, and the Borbon Basin to the north. Faulting is present in all areas, some of considerable horizontal and vertical displacement.

The depositional and structural history of coastal Ecuador is quite evident in the rocks of the area. Both are governed entirely by the adjacent Andes Mountains and the Pacific Deep.

The petroleum deposits of Ecuador are confined to the area known as the Santa Elena Peninsula. Production is from the Socorro and Atlanta formations (Middle Eocene). In addition, there is some shallow pit and chert production. Accumulation is caused by a combination of structure and stratigraphy.

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MARCELLUS FORMATION IN NEW JERSEY

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The Marcellus formation in New Jersey was first described by Kitchell in 1855, although earlier remarks of Rogers in 1836 suggest that he was aware of the presence of the formation within the State. In 1868 Cook described the formation and its fauna, but, since his day, the location of the outcrop of Marcellus in New Jersey has been lost. Recently the author rediscovered the formation, and this paper contains a description of it and a faunal list.

PLEISTOCENE DRIFT SHEETS IN THE LETHBRIDGE REGION, ALBERTA, CANADA

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Three Pleistocene drift sheets exposed along the Oldman River Valley in southern Alberta are assigned tentatively to the Iowan and Tazewell-Cary substages of the Wisconsin glacial stage. The "interglacial" beds of previous writers are considered to be glacial lake beds deposited in front of the retreating Tazewell-Cary ice sheet. An important retreat and readvance of the ice to the position of the Lethbridge moraine is evidenced within the area. The Saskatchewan gravels, which underlie the drift, are believed to be nonglacial in origin and probably preglacial in age. As such they cannot record a pre-Kansan "Albertan" stage of glaciation as was proposed by G. M. Dawson.

LANDFORMS NEAR BIG DELTA, ALASKA

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Photo interpretation and field studies made on foot or by helicopter show that the present geomorphic character of the area near Big Delta, Alaska, is principally influenced by the rise of the Alaska Range and subsequent glaciations. Following uplift, large alluvial fans were deposited along the north slopes of the range. They deflected the Tanana River northward against an upland of very old schists creating an asymmetrical valley.

Glaciation and glacio-fluvial deposition produced the present surface in the Delta Region south of the Tanana River. The oldest and most extensive moraines have been traced for about 35 miles.

This glaciation was separated, by a considerable period of time, from a later intense phase of Alpine Glaciation in which the trunk glaciers extended as much as 12 miles beyond the Alaska Range but did not coalesce into a piedmont lobe. The early piedmont phase has been designated the Delta Lobe Glaciation and the intense Alpine phase, Valley Tongue Glaciation. The Valley Tongues are only some of a series of progressively weaker ice advances that have continued to the present. The latest of these advances probably reached its maximum about the middle of the eighteenth century. Since that time there have been minor fluctuations and isolated instances of glacier activity. The most recent was that of the Black Rapids Glacier which advanced 4 miles in the winter of 1936–1937.

Interesting terrain features of this region are streams that cut across rock structures, glaciers that flow in fault trenches in the heart of the Alaska Range, a notable example of a tind, a well-preserved series of terraces, and deposits of both ancient and modern loess. Several types of glaciation—Alpine, Intense Alpine, and Mountain Piedmont—are represented.

To describe more accurately the conditions found in the region, the author proposes certain geomorphic concepts: vertical zonation of morphogenetic regions and burial of hills in which there are categories resulting from alluviation and congeliturbation. In addition, distinctive hills, here called Cleavers, are recognized. They occur at the edge of the mountains and divide the Alpine glaciers as they advance from the mountains.

STRATIGRAPHY OF THE COASTAL PLAIN OF NEW JERSEY

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Walter B. Spangler and Jahn J. Peterson (1950) described the geology of the coastal plain of New Jersey and adjacent States southward through Virginia. Much of the article was devoted to New Jersey. Because it contained numerous erroneous statements, and because the article has been widely read, it seems necessary to offer corrections. This paper presents such corrections and contains several new geologic sections including some along the recently constructed New Jersey Turnpike. It summarizes our knowledge of the stratigraphy of the area.

TACONIC THRUST IN SUDBURY, VERMONT

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Along the northern end of the Taconic Range east of Sudbury, Vermont, Taconic slates lie on a plate of overturned Beldens marble of the Subdury nappe, which in turn bevels the core of the Middlebury synclinorium, as described by Cady. The slates continue in contact with the lower Ordovician Beldens to southeast of Sudbury town hall, where a contorted recumbent marble fold has enveloping basal Chazyan dolomite rock trending into the fault line and passing beneath the slates. Southward, progressively younger formations appear until the Taconic slates lie on medial Trentonian black slate contained in two principal southeast-trending recumbent synclines; the outcrop of slate in the first terminates just north of the gap above Hyde Manor, and of the second in the woodland half a mile to the south. Red and green Taconic slate lies on the west limb of the second syncline just east of the highway a quarter of a mile north of the side road at the northeast end of Lake Hortonia.

RELATION OF THE FOLDED APPALACHIANS TO THE CRYSTALLINE APPALACHIANS IN THE LIGHT OF GREAT SMOKY MOUNTAINS GEOLOGY*

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The folded Appalachians (Valley and Ridge province) is made up of folded and faulted Paleozoic sedimentary rocks of Cambrian to Pennsylvanian age. The crystalline Appalachians (Blue Ridge and Piedmont provinces), which lies to the southeast, is made up primarily of schists and gneisses, in which are embedded granitic plutons of various shapes and sizes. Are the crystalline Appalachians a basement older than the sedimentary rocks of the folded Appalachians, perhaps forming a geanticline complementary to the geosyncline in which the sedimentary rocks were deposited? Or are the schists and gneisses equivalent to at least a part of the sedimentary rocks, originally a part of the same geosynclinal prism but of different facies, subjected to metamorphism, metasomatism, and to forms of deformation that were different from those in the folded Appalachians? The Great Smoky Mountains, which lie in the intermediate zone of the Unaka Province, contribute to the solution of these problems, as they are made up of geosynclinal rocks that show increasing metamorphism and metasomatism toward the southeast. They have not, as yet, provided final answers to these questions because many complexities of the area have not yet been worked out; also, some answers may not be obtained here because of the lack of fossils in the rocks and the profound thrust faulting. Supplementary evidence may, however, be obtained in other places to the northeast and southwest along the strike of the intermediate Unaka Province.

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NATURAL RADIOCARBON MEASUREMENTS

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Some of the technique developments obtained in the Carbon 14 laboratory at the Lamont Observatory will be described. The use of a mercury shield inside the anticoincidence ring extends the range of the method from 25,000 to 35,000 years before present. Ages on samples of archeological and geological significance will be reported. Large samples of ocean water at great depth have been taken, the carbon extracted, and the Carbon 14 content measured. The possible significance of such results for oceanography will be discussed.

CLIMATIC PROBABILITIES IN IRAN

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Thousands of painstaking patient observers stationed all over the earth keep accurate weather records of temperature, precipitation, wind, humidity, and condition of the sky. Summation of all measures of a given kind are generally expressed in terms of the central tendency (usually the average) and the extremes. The average, as a measure of central tendency, indicates that the chances are approximately 50-50 that half of the measures will be above and half below this computed value In nearly all life's ventures we are desperately anxious to forecast more accurately than just our 50-50 (average) chances. Can the record of our weather experience give us better that a 50-50 forecast of our chances as we look to the future? The present study indicates that a forecast of 2 to 1, 10 to 1, or any other chance can be computed with just as much assurance as the even chance (50-50). To demonstrate the practicability of this added use of our weather records this paper will center attention on average monthly temperatures, and average daily maxima and minima temperatures in Iran. For example, the chances according to a 31-year record are 9 to 1 that the average daily minimum temperature in January at Teheran will not fall below 22° F, and that the average daily maximum in July will not rise above 101° F.

OUR SHRINKING GLOBE

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The classic contraction hypothesis is dusted off, revised, and applied as a panacea for many geological complaints. Fundamental to the entire idea is a once-liquid globe that has solidified up to the present to a depth of 1820 miles. This solidification was accompanied by a reduction in radius of approximately 140 miles and in circumference of 880 miles. As solidification proceeded downward the overlying segments sporadically grabened. In general, but not invariably, segments capped by the lighter sial lagged behind the sima-topped segments, both in time of collapse and in distance dropped. The downward movement was of three types: (1) dropping of large segments, perhaps up to continental or ocean-basin size, as a unit; (2) fragmentation of the segment, with different parts thereof dropping varying distances; and (3) fragmentation at depth, with at least some of the downfaulted blocks translated upwards into downwarps. Some rotation of the blocks took place as they dropped.

With depth the fault planes bounding the crustal segments probably approach the vertical, for that is the direction in which contraction by solidification takes place. Because these planes converge toward the center of the earth, when a block drops it exerts horizontal pressures both within itself and within the adjacent blocks. These pressures are relieved by upwarping, folding, and thrust faulting.

Differential settling of earth segments could explain such geological mysteries as glacial climates, world-wide warm epochs, submarine canyons, alternating submergences and emergences of the continental platforms, and the Lipalian and lesser intervals.

CHRONOLOGY OF POST-GLACIAL TIME

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Increasing need has arisen for a standard chronology which will conveniently subdivide geologic time from the Last Glacial Maximum to the Present. Current methods of subdividing post-Glacial time are generally restricted to events at the retiring ice border and are incapable of evaluating time after the disappearance of the ice.

It is here proposed to set up a chronology based on land movements since these can be shown to have begun early in the history of ice recession, to have been continental in extent, to have taken place in four great uplifts separated by prolonged intervals of stability, and to be continuing actively today near the former ice center. Land movements during and following disappearance of the last ice sheet have repeatedly changed the patterns of land and water, and controlled the paleogeography. Their continental character and their effect on the water planes of the glacial ocean make possible eventual correlation with land movements and marine stages in Europe. Such a tectonic chronology can be illustrated by paleogeographic maps which are of use in several branches of science.

FLEXURES OF GLACIAL UPWARPING IN NEW ENGLAND

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Surveys of glacial water levels in New England show complicated local patterns of crustal dislocation superposed on the evidence of more regular continental upwarping. The northerly and northwesterly rise of glacial shore lines toward a former ice center not only is distinctly broken by hinge lines, but has suffered cross warping or flexuring to a degree bordering on true faulting. A regular pattern of isobases cannot be drawn across adjacent valleys such as the Quinnebaug and Blackstone, which are separated by a flexure that increases from south to north until at Worcester, Mass., it seems to become a faulted monocline with a displacement of 300 feet in a distance of 4 miles dislocating the glacial shore lines and the Schooley peneplane by that amount. In similar manner a glacial marine water plane in the Merrimac Valley of eastern New Hampshire has been upwarped higher than contemporary lake levels in the Connecticut Valley, which were originally 200 feet above it. Only through shoreline studies is it possible to detect flexuring of this sort which is utterly different from the gentle and uniform warping of the Great Lakes. Flexuring is found in the same region with extraordinary tilting of glacial water levels amounting to 18 feet per mile in northern Connecticut, and 24 feet per mile in northeastern Massachusetts, and is known only in the belted crystalline rocks of the older Appalachian Province.

NEED FOR ESTABLISHMENT OF A NATIONAL AND INTERNATIONAL MINERAL POLICY

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At present the United States does not have an overall, co-ordinated long-range plan of mineral development and mineral use. If we are to maintain a strong economy we must be aware of the extent of our existing resources and the demands the future will place on them. Such an awareness necessitates a survey of the world's mineral resources. Our way of life is based on a mineral economy. We can maintain our high standards of living and a strong world position only if our use of the

nonrenewable mineral resources is consistently maintained at a high level. Such a sound utilization of mineral resources can be achieved only if we know, for a period of many years, how much of each resource we can obtain in this country and how much must come from abroad. It is thus the purpose of this paper to discuss the problems of establishment of a sound mineral policy and the geographers' part in this program.

COMPOSITION AND STRUCTURE OF THE DEPTHS OF EARTH DERIVED FROM METEORITES

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The composition and structure of the deeper parts of the Earth's mantle and of the outer part of its core are assumed to be like the mantle and core of a hypothetical planet, called the Meteorite Planet, from which the meteorites—but not the asteroids—were derived, but to differ profoundly with its fragments, the meteorites, both in composition and structure. The Meteorite Planet is postulated to have had a diameter of the order of 1500 km., a mantle of simatic rock, and a core of nickel iron. The fragments of the Meteorite Planet, which varied in size from the order of 100 km. to sands, are postulated to have resulted from a combination of tidal forces and a quasi-volcanic explosion, probably assisted by a glancing collision.

The composition of the Meteorite Planet or of the depths of Earth cannot be derived directly from meteorites, whose composition and structure were profoundly altered by the catastrophe in which they were formed; but, if the suggested mechanism accounts for the peculiarities of the meteorites, it is possible to reconstruct their parent body and thus arrive at the composition of those parts of the depths of Earth that correspond to the vanished Meteorite Planet. From the reconstructed planet it is concluded that neither the mantle of the Meteorite Planet nor that of the Earth ever contained any significant quantity of metallic nickel-iron, and that the outer part of the terrestrial core is composed of nickel-iron similar to that found in iron meteorites except that it is richer in ferrous sulphide and other substances that are volatile at the temperature of molten iron.

ALASKA PETROLEUM IN RELATION TO GEOLOGIC HISTORY

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The petroleum-reserve possibilities of Alaska may be considered on the basis of five geologic belts, similar to and continuous with belts of the western United States: (1) The southernmost is the analogue of the Pacific coastal ranges and valleys, where Tertiary marine rocks have produced oil (Katella field) and numerous seepages (Katella and Yakataga areas), and where Jurassic rocks have given rise to seepages and showings in wells in areas bordering Cook Inlet and Shelikof Strait. In much of this belt Tertiary rocks are nonmarine (Matanuska Valley and Cook Inlet), and Jurassic sandstones are low-permeability graywackes. (2) Similar to the Sierra-Cascade belt, this belt includes the Alaska and Aleutian ranges and the Talkeetna and Wrangell mountains. (3) The broad interior region, drained by the Yukon, Tanana, Koyukuk, and Kuskokwim rivers, has much in common with the Basin and Range and Plateau provinces of the States. Although this belt is in regional aspect structurally complex, it does include several areas of slight to moderate deformation. Carboniferous and other systems contain much limestone, dolomite, and black shale, and the Triassic contains oil shale. Upper Cretaceous rocks include much sandstone and in part indicate transgressive and regressive marine sedimentation. (4) The Brooks Range is the Alaskan counterpart of the Rocky Mountain System. (5) The Arctic Slope region is similar in structure, stratigraphy, and paleontology to the Great Plains; Cretaceous rocks of the Arctic Slope have produced gas and oil, and Paleozoic rocks afford possibilities of local accumulations. The area of the Arctic Ocean off Alaska was a platform or shield until Cretaceous time.

LATE WISCONSIN TERRACES AND SOILS NEAR ST. LOUIS, MISSOURI

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The radiocarbon determination of the age of the Festus terrace at Bonfils, Missouri, by Libby provides a basis for the interpretation of the most recently developed river terraces and soils in eastern Missouri. The Festus terrace is a climatic terrace of Mankato age; the lower, Deer Plain terrace, a climatic terrace of Cochrane age. The "flood plain" shows some characteristics of a climatic terrace and may also merit such a designation. These terraces are more closely related to the fluctuations between pluvial and interpluvial episodes of the semiarid regions than to the glacial and interstadial episodes of Northeastern United States. However, the pluvial episodes are correlated with the glacial advances.

Two early and middle Wisconsin loess sheets are correlated with the Farmdale and Peorian loesses of Illinois. A loess deposit of Mankato age is described. One small deposit of post-Mankato loess is described. Black prairie soils of this area were formed during the post-Cochrane xerothermic period. They now show polygenetic features for in some places they have either been eroded, altered, or mantled with silt.

A tentative correlation of these terraces, and the episodes of erosion and deposition, with those of other parts of the United States is presented.

RECENT HISTORY OF BLACK RAPIDS GLACIER, ALASKA*

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The Delta River valley displays evidence of two advances of Black Rapids glacier prior to the well-known advance of 1937. During the earlier advance, the glacier extended 2 miles into and down the Delta valley, diverting the Delta River and its westward-flowing tributaries. The end moraine, part of which lies east of the Delta River, and a recessional moraine are largely forested, locally covered with turf, and bear lichen-covered boulders. During the later advance, the glacier was confined to the west side of the Delta River and fell short of the earlier advance by about 1 mile. The moraine is fresh looking, with few trees, no turf, and boulders on which lichen growth is scant or lacking.

The advances cannot be dated precisely by the age of trees growing on moraines because, owing to strong winds and near-timber-line altitude (2200 feet), trees may not become established for 30 to 50 years (the 1937 moraine remains treeless after 14 years). On the earlier moraine, tree-ring counts indicate that the oldest trees (spruce) are 130 to 135 years old, except for one rotten-centered spruce estimated to be 200 to 250 years old. A mature forest in front of this moraine has spruce trees estimated to be 500 years old. On the later moraine trees are 65 to 80 years old.

Castner and Canwell glaciers, 10 miles to the southeast, have similar records, and study of aerial photographs suggests that many glaciers in the Central Alaska Range have had advances correlative with those of Black Rapids glacier.

SEDIMENTARY PROCESSES ALONG THE SOUTH SHORE OF LAKE ERIE, VICINITY OF SANDUSKY, OHIO

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A brief outline is presented of the current progress of the Lake Erie Geological Research Program. The following techniques used in the investigation are described: (a) Bottom sampling; (b) Map-

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* Publication authorized by the Director, U. S. Geological Survey

ping of bottom topography with echo-sounding equipment; and the correlation of echo types with bottom materials; (c) Charting of surface and subsurface currents in shallow water; (d) Charting of paths of sediment transport by marking grains and following their movement; (e) Planning of offshore operations with respect to problems of horizontal control.

Mineralogical and textural variations in the sediments analyzed are discussed and interpreted.

GEOLOGICAL FOUNDATION OF EXPLORATION FOR PETROLEUM IN JAPAN

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The paper is based on unpublished material contributed to the Japanese Petroleum Resources Development Promotion Council by its members. It summarizes the author's synthesis of the historical record which suggests a possible long-term continuity underlying successive phases of tectonic evolution in Northern Japan.

Within the framework of geological history and paleogeography so developed, the salient geological characteristics, contributing to or limiting the actual or possible occurrence of petroleum in many now-separated sedimentary basins, are examined.

The sources of known oil occurrences are shown to be related to facies verging on geosynclinal. Their relationships to former partially enclosed seas are notable though not quite universal. Scarcity of suitably porous reservoir rock is in many places a limiting factor to economic development, mitigated to some extent by the variable and as yet unpredictable degree to which volcanic tuffs sometimes provide reservoir rock conditions.

The more economically successful developments of the past have been confined to the Japan Sea geosynclinal areas, containing source rocks not older than Middle or Upper Miocene. Here folding originated at the close of Miocene times but has recurred later particularly in the Plio-Pleistocene. The influence of successive folding movements on migration, and the effects of erosion and vulcanicity are discussed. Scope for further exploration in this belt is becoming restricted, though further successes are still considered quite possible.

In the Yezo Karafuto geosyncline of Hokkaido, prospects extending back to the Cretaceous are not disproved, but the effect of pre-Miocene periods of movement superimpose further uncertainties. Prospects in East Hokkaido, the Kanto district near Tokyo, and Shizuoka are also discussed.

GEOGRAPHIC RESEARCH PROGRAM OF THE OFFICE OF NAVAL RESEARCH

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The Geography Branch of the Office of Naval Research supports a program of basic and applied research in geography carried on at some 50 universities and research institutions. The basic program consists of research projects proposed by the investigators. The objective is the increase of geographic knowledge; immediate practical application is not necessarily envisaged. The applied program consists of projects directed toward a practical end useful to the Navy.

OIL POSSIBILITIES OF AUSTRALIA

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The search for oil in Australia has been in progress for over half a century, and, although exploratory drilling has been carried out in 8 of its 14 sedimentary basins, only 2 basins have yielded good shows of oil; these have been actively drilled in recent years with negative results.

This failure to find oil in an area as large as the United States cannot be attributed to handicaps imposed by unfavorable mining laws or to the lack of enterprise or technical ability. Since the modernizing of the petroleum laws in the late 1930's, several large foreign companies have had the full cooperation of the Commonwealth and State governments in their search for oil in the more promising sedimentary basins.

These unsuccessful results can be attributed to unfavorable geological factors; the most obvious is the scarcity of large sedimentary basins with a fair thickness of unmetamorphosed marine sedimentary strata. One or two basins on the west coast come near fulfilling these conditions and may yield some oil when they are properly tested.

The geochemical-pedologic approach to chronology of archaeological sites here suggested appears to be a new one and is subject to considerable refinement. Our report is preliminary and our conclusions are subject to revision.

HYPSOMETRIC FUNCTION FOR SMALL DRAINAGE BASINS

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The quantitative description and comparison of small drainage basins is aided by use of percentage hypsometric curves in which relative horizontal cross-sectional area of the basin is plotted on the abscissa, relative height above basin mouth on the ordinate. The following function fits closely the natural hypsometric curves and has proved generally satisfactory as a means of describing the hypsometric characteristics of a homogeneous region:

$$y = \left[\frac{d - x}{x} \cdot \frac{a}{d - a}\right]^z$$

where d and a are constants, d always greater than a, and the exponent z is positive or zero. The curve segment used lies between the points $x = a$, $y = 1$, and $x = d$, $y = 0$.

Families of curves are determined by the ratio a/d, which influences the slope of the curve at its point of inflection. Within a given curve family the exponent z determines the area under the curve and provides a measure of the stage of erosional development of the region, which may be expressed by the value of the integral of the function between the limits a and d.

Applications of the hypsometric function to mature drainage basins of the third and fourth orders in homogeneous rock materials has shown that values of r of 0.1 to 0.25 with integrals ranging from 0.4 to 0.6 are typical. It is hoped that the hypsometric function may have practical applications in the calculation of runoff, sediment load, and intensity of land erosion within drainage basins of various orders of magnitude and over a wide range of stages of topographic development.

GEOLOGY AND OIL FIELDS OF BRAZIL

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With a total land area of 3,286,170 square miles, Brazil has approximately 1,187,000 square miles, or 36 per cent, in sedimentary basins sufficiently large to be interesting from a petroleum-exploration viewpoint. The average thickness of sediments in those basins where information is available is of the order of 7500 feet. Nine oil fields have been discovered in the Reconcavo area of Bahia where daily production of crude oil is now 2500 barrels.

GEOGRAPHIC WORK IN NEW YORK STATE GOVERNMENT

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The New York State Department of Commerce is unique among the 19 State Departments in that it was not established to administer a particular law.

The wide latitude of function possible, and the fact that this Department is charged with the economic development of a large and populous area makes it a fertile field for the application of geographic training and techniques.

Several of the projects carried on by this Department of direct interest to geographers are:

An inventory of New York State's natural resources, particularly minerals, water, forests, soils, and climate;

Special area studies to determine the dominant industrial-location factors;

The preparation of a new six-color physiographic map of the State and eight surrounding States to be used principally in industrial promotion work.

ABSOLUTE AGES OF RADIOACTIVE MINERALS FROM THE APPALACHIAN REGION

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All available absolute age determinations made on radioactive minerals from the Appalachian region have been re-estimated in the light of presently accepted formulae and constants. They appear to record four orogenies. Two, roughly 800 and 600 million years ago, were Precambrian and are recorded only along the western edge of the crystalline Appalachians. The Taconian, 350 million years ago, affected a belt in the western part of the crystalline Appalachians and may also have been represented in eastern Massachusetts. The Acadian, 260 million years ago, affected eastern New England. Curiously the Appalachian orogeny is feebly or not at all recorded. The igneous rocks of the late Triassic appear to be about 170 million years old.

IDENTIFICATION OF FEATURES NAMED BY AMUNDSEN IN THE QUEEN MAUD RANGE

Captain Harold E. Saunders, USN (Rtd.)
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The Norwegian explorer Roald Amundsen, returning in 1912 from his conquest of the South Pole, brought with him only a very small-scale map and a collection of photographic views. His map was schematic, and his pictures lacked the systematic character associated with modern survey photographs. In fact, by the time his narrative and his photographs were published, three views of one of the important mountains he discovered carried three different names!

Because of fog and snow prevailing as he traveled both ways through the Queen Maud Range it was most difficult for Amundsen, from the ground, to give a connected picture of the country. It has been vastly more difficult for cartographers and geographers, in later years, to identify correctly the many features he named from the admirable aerial photographs taken by McKinley on the South Polar Flight and the ground photographs taken by Gould on the Southern Sledge Journey of the First Byrd Antarctic Expedition.

After over 20 years of study, it is felt that this has now been accomplished. In this paper there is given a new sketch map of the area concerned, supplemented with photographs of the principal geographic features, correctly named.

TIME AND TRACE METALS IN ARCHAEOLOGICAL SITES

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Geochemical and morphological expressions of soil age may be useful in approximate dating of middens and artifacts associated with soil profiles. Since a midden is a geochemical anomaly as a rule, the establishment of the background levels and trends for certain chemical elements constituting the anomaly is generally a direct function of time. Certain metallic constituents, notably copper,

zinc, gold, nickel, lead, and possibly mercury and tin are especially useful for the purpose. The common background levels of these metals are from a few parts per million (Zn, Cu, Ni) to small fractions of 1 part per million (Ph, Au, Hg); their zonations in the soil horizons and the forms of their occurrence are generally diagnostic of the pedogenic environment. The magnitudes of these trace metals in midden materials may be 10^0– 10^1– 10^2– 10^3 times the background values, depending on kind and age of midden, its stratigraphic position, and other variables.

Stratigraphic position of stone artifacts in soil profiles is generally indicative of their approximate age, provided the age of the soil profiles can be surmised. The common difficulty of archaeologists unfamiliar with soils and pedogenesis in recognizing extrusive or intrusive artifacts is eliminated easily, in most cases, by a close analysis of the soil structure and other pertinent features of the profile.

INDEX TO VOLUME 62 (JULY—DECEMBER)*

ABBOTT, A. T.: Tumac Mountain, a postglacial cinder cone in Washington state *1495*
Absolute ages of radioactive minerals from the Appalachian region. By John Rodgers *1560*
Abundance of elements in igneous rocks and in meteorites, a report of progress. By L. H. Ahrens *1419*
Accumulation and ablation of the Seward-Malaspina glacier system, Canada-Alaska. By R. P. Sharp 725, *1512*
ADAMS, J. E.: Late Paleozoic reef sequences in West Texas *1495*
Age determinations by Carbon 14. By J. L. Kulp *1456*
— of mineralization: thermoluminescence and radioactivity of fluorite. By J. M. Parks, Jr. and D. F. Saunders *1468*
AHRENS, L. H.: Abundance of elements in igneous rocks and in meteorites, a report of progress *1419*
—: Ionic radii of the elements *1419*
—: Quantitative spectrochemical analysis of silicates: a scheme of analysis *1420*
Aids for single-crystal techniques. By Gabrielle Donnay and J. D. H. Donnay *1431*
AITKEN, J. M.: Petrology and structure of the Hebron gneiss, Connecticut *1545*
Alaska
  Accumulation and ablation of Seward-Malaspina glacier system. By R. P. Sharp 725
— petroleum in relation to geologic history. By T. G. Payne and George Gryc *1557*
Aleutian Trench
  Submarine geology of the Gulf of Alaska. By H. W. Menard and R. S. Dietz 1263
Algonkian of Arizona, Nankoweap group of the Grand Canyon. By C. E. Van Gundy 953
Allard Lake ilmenite deposits. By Paul Hammond *1448*
ALVAREZ, MANUEL, JR.: New oil develpoments in Mexico in relation to their regional setting *1545*
ALLEN, V. T., and FAHEY, J. J.: Salite and actinolite at Iron Mountain, Missouri *1420*
Ammonoid from Lake Tahoe. By E. R. Larson and V. P. Gianella *1522*
Analyses
  Biogeochemical
    San Manuel copper deposit, Pinal County, Arizona. By H. V. Warren, R. E. Delavault, and R. I. Irish 919
— of fossil reef-type facies. By H. A. Lowenstam *1506*
— — rocks and sediments of San Francisco Bay, California, for use in engineering construction. By P. D. Trask and J. W. Rolston 1079
ANDERSON, C. A.: Older Precambrian structure in Arizona 1331
Angiosperms gradually assumed dominance. By D. I. Axelrod *1496*
ANSTEY, R. L.: Geographic work of Arnold Guyot *1545*
ANTEVS, ERNST: Arroyo cutting and filling *1495*
—: Glacial clays in Steep Rock Lake, Ontario, Canada. 1223
APPEL, E. T.; MAYNARD, J. E.; and PLOGER, L. W.: Possible diatreme in Syracuse, New York *1421*
Arizona
  Biogeochemical data from the San Manuel copper deposit, Pinal County. By H. V. Warren, R. E. Delavault, and R. I. Irish 919
  Nankoweap group of the Grand Canyon Algonkian. By C. E. Van Gundy 953
  Older Precambrian structure. By C. A. Anderson 1331
— structures symposium
  Older Precambrian structure in Arizona. By C. A. Anderson 1331
ARNOLD, Z. M. (With R. M. KLEINPELL): Cretaceous in the Philippines *1455*
Arroyo cutting and filling. By Ernst Antevs *1495*
ARTHUR, J. D.: Foundation and abutment treatment—McNary Dam, Oregon and Washington *1496*
Association of perthitic microcline with highly undulant or granular quartz in some calcalkaline granites. By Felix Chayes *1429*
Atlantic Coastal Plain, Geophysical investigations in the emerged and submerged. Part VI: The Long Island area. By J. E. Oliver and C. L. Drake 1287
Aurora siltstone member (new name). By Wallace de Witt, Jr. 1347
Aurostibite—a new mineral in the pyrite group. By A. R. Graham and S. Kaiman *1444*
AVERITT, PAUL: Status of summary coal-resource surveys, November 1, 1951 ..... *1421*
AXELROD, D. I.: Angiosperms gradually assumed dominance *1496*
AXELROD, J. M., *et al.*: Phosphate mineralization at Bomi Hills and Bambuta, Liberia, West Africa *1421*

BAILEY, E. H. (With L. G. BERRY and J. J. FAHEY): Robinsonite, a new lead antimony sulphide *1423*
BAKER, C. L.: Development of Dakota Basin in South Dakota *1531*
—: Pediment broadening in South Dakota badlands *1531*
—: Pleistocene in western South Dakota *1531*
—: Yardangs in South Dakota badlands *1532*
BAKER, N. E., and HENSON, F. R. S.: Geological conditions of oil occurrence in Middle East fields *1546*
BALDWIN, BREWSTER: Chert and volcanic ash east of Sioux Falls, South Dakota *1532*
—: Geology of the Sioux formation *1532*
Baltimore gabbro, Maryland, Petrology of. By Norman Herz *979*
BANDY, O. L.: Bathymetric distribution of some shallow-water foraminifera in the Gulf of Mexico *1521*
—, and MERRIAM, R. H.: Test wall microstructure as a basis for separating *Nonion* and *Elphidium* *1521*
Barite concretions from the ocean floor. By Roger Revelle and K. O. Emery 707
BARNES, V. E.: New tektite areas in Texas *1422*
Bartholemew siltstone member (new name). By Wallace de Witt, Jr. 1347
Basin sediments off Southern California. By K. O. Emery and S. C. Rittenberg *1501*
Bastnaesite discoveries near Mountain Pass, California. By L. C. Pray and W. N. Sharp *1519*
BATES, T. F. (With C. E. WEAVER): Mineralogy, petrography, and petrology of the K-bentonites *1488*
BÅTH, MARKUS: Initial motion of the first longitudinal earthquake wave recorded at Pasadena and Huancayo *1525*
Bathymetric distribution of some shallow-water foraminifera in the Gulf of Mexico. By O. L. Bandy *1521*
BAUER, H. L. (With V. R. WILMARTH *et al.*): Uranium in fluorite deposits *1543*
BECK, C. W. (With D. B. GIVENS): New basic copper phosphate mineral from Santa Rita, New Mexico *1442*
— (With R. A. Rowland): Determination of small quantities of dolomite by differential thermal analysis ... *1473*

* Full title of papers are in **boldface** type; page numbers of abstracts are in *italics*.

† Indicates a Short Note.

Bedrock deformation of late Quaternary age at Tiger Butte, northeastern Montana. By F. S. Jensen..... *1452*

Benioff, Hugo: Further improvements in a capacity-transducer seismograph..... *1525*

—: Mechanism of earthquake generation..... *1526*

—: Sound waves in the atmosphere generated by a small earthquake..... *1525*

Berea sandstone and associated rocks in northeastern Ohio and northwestern Pennsylvania. By Wallace de Witt, Jr..... 1347

Berg, D. A. (With J. P. Gries): Problems of the Minnelusa formation in the Black Hills..... *1535*

Berman, Joseph: Studies of metamict minerals. (I): Methods and procedures..... *1422*

Bermuda

Study of some Bermuda rocks. By Fred Foreman..... 1297

Beroni, E. P. (With G. B. Gott and D. G. Wyant): Uranium in black shales, lignites, and limestones in the United States..... *1535*

— (With D. G. Wyant and H. E. Granger): Some uranium deposits in sandstone..... *1544*

Berry, L. G.; Fahey, J. J.; and Bailey, E. H.: Robinsonite, a new lead antimony sulphide..... *1423*

Bertrand, Kenneth (With F. T. Thwaites): Pleistocene geology of the Door Peninsula, Wisconsin..... *1485*

Bever, J. E.: Petrology of the Guffey-Micanite region, Colorado..... *1423*

Biogeochemical analyses

San Manuel copper deposit, Pinal county, Arizona. By H. V. Warren, R. E. Delavault, and R. I. Irish..... 919

Biochemistry

Geologic history of sea water: an attempt to state the problem. By W. W. Rubey..... 1111

Biological and physical-chemical conditions in Newport Bay, California. By R. E. Stevenson and K. O. Emery..... *1482*

Black, R. F.: Graphs for visual comparison of several factors in heat exchange near Barrow, Alaska..... *1546*

—: Structures in ice wedges of northern Alaska..... *1423*

Blanton, S. L., Jr.: Origin of offshore bars..... *1424*

Blister hypothesis and the petrogenic cycle. By C. W. Wolfe..... *1491*

†**Blue Ridge Front—a fault scarp.** By G. W. Stose and Anna J. Stose..... 1371

Boos, M. F.: Distribution of impure marbles and lime-silicate members in the Idaho Springs formation west of Denver, Colorado..... *1533*

Borg, Iris (With David Griggs *et al.*): Deformation of the Yule marble: Part IV—Effects at 150°C..... 1385

Botts, A. K.: Geogenic Jersey..... *1547*

Bowen, A. S.: Mississippian scolecodonts near Chardon, Ohio..... *1424*

Bowen, N. L., and Tuttle, O. F.: Synthetic granites and their melting behavior under high H_2O pressures..... *1425*

— (With O. F. Tuttle): Four series of alkali feldspars... *1486*

Bowsher, A. L., Sr. (With J. T. Dutro, Jr. and W. P. Brosgé): Facies in Carboniferous rocks of northern Alaska..... *1434*

Bradley, W. F. (With R. E. Grim and W. A. White): Petrology of the Paleozoic shales of Illinois..... *1445*

Breccia pipes of the Terlingua district, Texas. By G. A. Thompson..... *1512*

Brill, K. G., Jr.: Permo-Pennsylvanian zeugogeosyncline of Colorado and northern New Mexico..... *1425*

Brooker, E. J. and Nuffield, E. W.: Studies of radioactive compounds: IV—Pitchblende from Lake Athabaska..... *1425*

Brosgé, W. P. (With J. T. Dutro, Jr., and A. L. Bowsher, Sr.): Facies in Carboniferous rocks of northern Alaska..... *1434*

Brown, Harrison, *et al.*: Isotopic composition of lead and the ages of minerals in a Precambrian granite.... *1426*

Brown, W. R.: James River synclinorium and related structure in the western Virginia Piedmont..... *1547*

Bryant, D. L.: Stratigraphy of a Pliocene vertebrate fossil locality near Prescott, Arizona..... *1496*

Bucher, W. H.: Infolded mid-Ordovician limestone on Precambrian north of Peekskill, New York, and its bearing on the region's orogeny..... *1426*

—: Preservation of the texture of echinoderm plates in metamorphosed rocks..... *1548*

Buffam, B. S. W.: Uranium deposits, Beaverlodge area, Saskatchewan, Canada..... *1427*

Buffington, E. C.: Gullied submarine slopes off Southern California..... *1497*

Burke, H. W. (With P. E. Cloud, Jr., and R. G. Schmidt): Geology of Saipan, Mariana Islands..... *1499*

Burwell, E. B., Jr.: Influence of minor geologic structures on dam construction..... *1427*

Buwalda, J. P.: Transportation of coarse material on alluvial fans..... *1497*

Byerly, Perry, and Eaton, Jerry: Valley wave..... *1526*

California

Engineering geology of San Francisco Bay. By P. D. Trask and J. W. Rolston..... 1079

Mount Lincoln-Castle Peak area, Sierra Nevada. By F. S. Hudson..... 931

Stream gradients and Monterey sea valley. By A. O. Woodford..... 799

Callaghan, Eugene: Distribution of intermediate and basic igneous rocks in the Tertiary of western United States..... *1428*

Callahan, J. T.: Geology of the Glen Canyon group between Lees Ferry and Tuba City, Arizona..... *1498*

Cambrian high in eastern Nevada. By F. W. Christiansen *1498*

Cameron, E. N. (With W. T. Holser *et al.*): Notes on the geochemistry of beryllium..... *1450*

Canada

Accumulation and ablation on Seward-Malaspina glacier system. By R. P. Sharp..... 725

Glacial Clays in Steep Rock Lake, Ontario. By Ernst Antevs..... 1223

Cape Cod, Massachusetts, Ocean-bottom photographs of the neritic and bathyal environment south of. By John Northrop..... 1381

Caras, Alice (With C. W. Wolfe): Unit cell of schairerite *1491*

Carpenter, L. C.: Evidence of a post-Laramide normal fault zone north of the Ferris Mountains, Wyoming *1533*

Carron, M. K. (With J. M. Axelrod *et al.*): Phosphate mineralization at Bomi Hills and Bambuta, Liberia, West Africa..... *1421*

— (With W. T. Schaller): Margarite-ephesite series: theory versus fact..... *1476*

Carter, D. A.: Structural setting of the Kentucky-Illinois fluorspar district in the Eastern Interior Basin..... *1533*

Carter, G. F., and Sokoloff, V. P.: Humisol..... *1548*

— (With V. P. Sokoloff): Time and trace metals in archaeological sites..... *1560*

Caster, K. E., and Kjellesvig-Waering, E. N.: Concerning the Eurypterid *Megalograptus*, an Upper Ordovician anachronism..... *1428*

Castle Peak area, Sierra Nevada, California, Mount Lincoln-. By F. S. Hudson..... 931

Cathcart, S. H.: Ground-water problems in Pennsylvania..... *1548*

Cenozoic marine climates. By J. W. Durham..... *1433*

Chadwick, G. H.: Glacial waters in Catskill (New York) area..... *1549*

CHAPPELL, W. M., DURHAM, J. W., and SAVAGE, D. E.: Mold of a rhinoceros in basalt, lower Grand Coulee, Washington ... 907
Chardon siltstone member (new name). By Wallace de Witt, Jr. ... 1347
CHAYES, FELIX: Association of perthitic microcline with highly undulant or granular quartz in some calcalkaline granites ... 1429
Check list on earthquakes with surface faulting. By C. F. Richter ... 1528
Chemical analyses of constituents of clarain. By R. M. Kosanke ... 1455
— characteristics of the Jacksonburg formation. By C. A. Warmkessel and H. R. Gault ... 1487
— composition of North American Precambrian slates. By R. H. Nanz, Jr. ... 1466
Chert and volcanic ash east of Sioux Falls, South Dakota. By Brewster Baldwin ... 1532
CHESTERMAN, C. W.: Nephrite in Marin County, California ... 1517
CHIANG, YAO (With W. J. SMOTHERS): Differential thermal curves of some Arkansas lignites ... 1480
CH'IE, C. S. (With F. J. TURNER): Deformation of Yule marble: Part III—Observed fabric changes due to deformation at 10,000 atmospheres confining pressure, room temperature, dry ... 887
Chlorite-calcite pseudomorphs after orthoclase phenocrysts, Ray, Arizona. By G. M. Schwartz ... 1476
CHRISTIANSEN, F. W.: Cambrian high in eastern Nevada 1498
Chronology of post-glacial time. By R. J. Lougee ... 1556
CLEAVES, A. B.: Geology in highway design and construction: the Pennsylvania Turnpike's western extension ... 1429
CLEMENTS, LYDIA (With THOMAS CLEMENTS): Evidence of Pleistocene man in Death Valley, California ... 1498
CLEMENTS, THOMAS, and CLEMENTS, LYDIA: Evidence of Pleistocene man in Death Valley, California 1498
Climatic probabilities in Iran. By E. E. Lackey ... 1555
CLOUD, P. E., JR.: Facies relationship of reefs ... 1499
—; SCHMIDT, R. G.; and BURKE, H. W.: Geology of Saipan, Mariana Islands ... 1499
Coal deposits and Cretaceous stratigraphy of the western part of Black Mesa, Arizona. By G. A. Williams ... 1514
COLEMAN, R. G.: Riebeckite from St. Peter's Dome, Colorado ... 1517
Collapse structure. By J. V. Harrison ... 1449
COLTON, R. B., and HOWARD, A. D.: Driftless areas in northeastern Montana ... 1429
Composite origin of submarine canyons. By F. P. Shepard 1512
Composition and significance of fluid inclusions in minerals. By Edwin Roedder ... 1472
— — structure of the depths of earth derived from meteorites. By P. S. Palmer ... 1557
Compression and extension experiments on dry Yule marble. By David Griggs and W. B. Miller ... 853
Compressional mountains and associated phenomena, Origin of. By J. L. Rich ... 1179
Concerning the Eurypterid *Megalograptus*, an upper Ordovician anachronism. By K. E. Caster and Erik. N. Kjellesvig-Waering ... 1428
Co-ordination models. By C. J. SCHNEER ... 1476
Copper
Biogeochemical data from the San Manuel copper deposit, Pinal County, Arizona, By H. V. Warren, R. E. Delavault, and R. I. Irish ... 919
COREY, W. H.: Southern California coastal paleogeography ... 1500
Coronites from the Preston gabbro, New London County, Connecticut. By C. B. Sclar ... 1477
Correlation
Principles for Precambrian of Minnesota. By F. F. Grout, J. W. Gruner, G. M. Schwartz, and G. A. Thiel ... 1017
CREELY, R. S. (With D. E. SAVAGE and B. A. OGLE): Subdivision of vertebrate-bearing nonmarine Pliocene rocks in west-central Contra Costa County, California ... 1511
Cretaceous deposits of the Punta San Isidro area, Baja California. By M. V. Kirk and J. R. MacIntyre ... 1505
— formations in part of Maryland and Virginia, Structural relations of. By N. H. Darton ... 745
— in the Philippines. By R. M. Kleinpell and Z. M. Arnold ... 1455
Cross-lamination in the Salt Wash sandstone member of the Morrison formation. By G. W. Weir ... 1514
CROUCH, R. W.: Significance of temperature upon the foraminifera from the deep basins off the Southern California coast ... 1521
Cryolite twinning. By J. D. H. Donnay and Gabrielle Donnay ... 1432
Crystal-fabric studies on the Emmons Glacier, Mount Rainier, Washington. By G. P. Rigsby ... 1510
Crystallography of jadeite (?) from near Cloverdale, California. By C. W. Wolfe and Daphne Riska ... 1491
CURTIS, G. H.: Mehrten formation erosional interval ... 1500
Cycle of mountain development. By J. L. Rich ... 1179

DAPPLES, E. C.: Sedimentary facies changes in coal strata ... 1430
DARTON, N. H.: Structural relations of Cretaceous and Tertiary formations in part of Maryland and Virginia 745
Dating the Wissahickon schist at Philadelphia, Pennsylvania By J. W. Frondel ... 1550
†**Deep-sea sands and submarine canyons.** By D. B. Ericson, Maurice Ewing, and B. C. Heezen ... 961
Deformation of Yule marble
Part I—Compression and extension experiments on dry Yule marble at 10,000 atmospheres confining pressure, room temperature. By David Griggs and W. B. Miller ... 853
Part II—Predicted fabric changes. By J. W. Handin and David Griggs ... 863
Part III—Observed fabric changes due to deformation at 10,000 atmospheres confining pressure, room temperature, dry. By F. J. Turner and C. S. Ch'ih ... 887
Part IV—Effects at 150°C. By D. T. Griggs, F. J. Turner, Iris Borg, and John Sosoka ... 1385
Deglaciation of north-central Baffin Island. By R. P. Goldthwait ... 1443
DELAVAULT, R. E. (With H. V. WARREN and R. I. Irish): Further biogeochemical data from the San Manuel copper deposit, Pinal County, Arizona ... 919, 1478
Determination of small quantities of dolomite by differential thermal analysis. By R. A. Rowland and C. W. Beck ... 1473
Development of Dakota Basin in South Dakota. By C. L. Baker ... 1531
— — melanterite and fibroferrite from gelatinous ferrous sulfate. By B. J. Scull ... 1520
Devonian faunas of the western Brooks Range, Alaska. By J. T. Dutro, Jr. ... 1434
DE WITT, WALLACE, JR.: Stratigraphy of the Berea sandstone and associated rocks in northeastern Ohio and northwestern Pennsylvania ... 1347
DIETRICH, RICHARD: Fish Creek phacolith, northwestern New York ... 1439
DIETZ, R. S.: Proposed geomorphic evolution of continental terraces ... 1501
— and MENARD, H. W.: Hawaiian swell, deep, and arch and the subsidence of the Hawaiian Islands ... 1431
— — —: Origin of the shelf-break ... 1501

DIETZ, R. S. (With H. W. MENARD): Mendocino submarine escarpment ... 1465
— (— —): Submarine geology of the Gulf of Alaska ... 1263
Differential thermal curves of some Arkansas lignites. By W. J. Smothers and Yao Chiang ... 1480
Disconformity at the contact of the Fox Hills sandstone and Hell Creek formation in northeastern Montana. By F. S. Jensen ... 1453
Distinction between the different members of the potash feldspar group using only a microscope. By L. Dolar-Mantuani ... 1431
Distribution of impure marbles and lime-silicate members in the Idaho Springs formation west of Denver, Colorado. By M. F. Boos ... 1533
— — intermediate and basic igneous rocks in the Tertiary of western United States. By Eugene Callaghan ... 1428
— — uranium deposits in the United States. By E. P. Kaiser and L. R. Page ... 1495
DOBROVOLNY, E. (With S. E. HORNER): Geological problems in highway design and construction in Kansas ... 1451
DOLAR-MANTUANI, L.: Distinction between the different members of the potash feldspar group using only a microscope ... 1431
Dolomite in the Arbuckle limestone, Arbuckle Mountains, Oklahoma. By W. E. Ham ... 1446
DONNAY, GABRIELLE, and DONNAY, J. D. H.: Aids for single-crystal techniques ... 1431
— (With J. D. H. DONNAY): Cryolite twinning ... 1432
DONNAY, J. D. H, and DONNAY, GABRIELLE: Cryolite twinning ... 1432
— (With GABRIELLE DONNAY): Aids for single-crystal techniques ... 1431
DOWNS, THEODORE: Mascall Miocene fauna and related assemblages from Oregon ... 1432
DRAKE, C. L. (With J. E. OLIVER): Geophysical investigations in the emerged and submerged Atlantic Coastal Plain. Part VI: The Long Island area ... 1287
DREIMANIS, ALEKSIS: Studies of Pleistocene stratigraphy along Lake Erie in southwestern Ontario ... 1432
Driftless areas in northeastern Montana. By R. B. Colton and A. D. Howard ... 1429
"Dry Creek formation" in southwestern Montana. By A. M. Hanson ... 1494
DU BOIS, E. P.: Interrelation of structure and Pennsylvanian sedimentation in Central Illinois ... 1433
Dugway area, Utah, Pleistocene valley sediments of. By R. L. Ives ... 781
DUFOUY-CAMET, J.: Petroleum exploration and development in France, 1950 and 1951 ... 1549
DURHAM, J. W.: Cenozoic marine climates ... 1433
—: Mode of growth in some echinoids ... 1434
—: Recent Mollusca and Tertiary correlations ... 1522
— (With W. M. CHAPPELL and D. E. SAVAGE): Mold of a rhinoceros in basalt, lower Grand Coulee, Washington 907
DUTRO, J. T., JR.: Devonian faunas of the western Brooks Range, Alaska ... 1434
—; BOWSHER, A. L., SR.; and BROSGÉ, W. P.: Facies in Carboniferous rocks of northern Alaska ... 1434
Dynamic role of dilatancy in the migration and accumulation of oil in metamorphic rocks: a hypothesis. By D. A. McNaughton ... 1507

EARDLEY, A. J.: Restudy of the type Wasatch ... 1435
Earthquake magnitude determination at Rome, Italy. By C. F. Richter ... 1529
EATON, G. P. (With J. W. PEOPLES): Magnetic susceptibility of chromite from Montana and its relation to other physical and chemical properties ... 1469
EATON, JERRY (With PERRY BYERLY): Valley Wave ... 1526
Ecology
Fossil fresh-water mollusks and ecological interpretations. By Teng-Chien Yen ... 1375
Economic geology
Biogeochemical data from the San Manuel copper deposit, Pinal County, Arizona. By H. V. Warren, R. E. Delavault, and R. I. Irish ... 919
Elements of a plan for research in mountain building. By J. W. Harrington ... 1449
EMERY, K. O., and RITTENBERG, S. C.: Basin sediments off Southern California ... 1501
— (With ROGER REVELLE): Barite concretions from the ocean floor ... 707
— (— R. E. STEVENSON): Biological and physical-chemical conditions in Newport Bay, California ... 1482
ENGEL, A. E. J., and ENGEL, C. G.: Origin and evolution of hornblende-andesine amphibolites and kindred facies ... 1435
ENGEL, C. G. (With A. E. J. ENGEL): Origin and evolution of hornblende-andesine amphibolites and kindred facies ... 1435
Engineering geology in Brazil. By P. P. Fox ... 1440
— — of San Francisco Bay, California. By P. D. Trask and J. W. Rolston ... 1079
†ERICSON, D. B.; EWING, MAURICE; and HEEZEN, B. C.: Deep-sea sands and submarine canyons ... 961
†— (With B.C. HEEZEN and MAURICE EWING): Submarine topography in the North Atlantic ... 1407
EVERHART, D. L., and WRIGHT, R. J.: Some geologic characteristics of uranium-bearing vein deposits ... 1436
Evidence bearing on the consanguinity of Missouri and Oklahoma Precambrian igneous rocks. By Forbes Robertson and Russell Maurer ... 1541
— of eustatic change in sea level in the Pennsylvanian of the southwestern United States. By H. R. Wanless and W. M. Merrill ... 1487
— — instability of Pacific basin. By Roger Revelle ... 1510
— — major fault truncating the eastern end of the Santa Monica Mountains, California. By G. J. Neuerburg ... 1509
— — Pleistocene man in Death Valley, California. By Thomas Clements and Lydia Clements ... 1498
— — post-Laramide normal fault zone north of the Ferris Mountains, Wyoming. By L. C. Carpenter ... 1533
EVITT, W. R.: Silicified Trenton trilobites from New York 1436
Evolution and stratigraphic significance of the late Paleozoic ostracode Coryellina. By I. G. Sohn ... 1482
— of Nantucket shore lines. By W. F. Jones and J. B. Lucke ... 1453
EWING, MAURICE, and PRESS, FRANK: Surface waves at Honolulu ... 1526
— — —: Surface waves from Atlantic earthquakes ... 1526
— — — : — — — Solomon Islands earthquake, 24 July 1950 ... 1527
— — —: Tide-gauge disturbances from the great eruption of Krakatoa ... 1527
—, PRESS, FRANK, and WORZEL, J. L.: Further observations of the T phase ... 1527
— (With FRANK PRESS): Two slow surface waves across North America ... 1528
†— (— D. B. ERICSON and B. C. HEEZEN): Deep-sea sands and submarine canyons ... 961
†— (— B. C. HEEZEN and D. B. ERICSON): Submarine topography in the North Atlantic ... 1407
— (— C. B. OFFICER, JR. and P. C. WUENSCHEL): Seismic-refraction measurements in the Atlantic Basin, Part II ... 1528
Extension experiments on Yule marble. By David Griggs and W. B. Miller ... 853

Fabric changes due to deformation at 10,000 atmospheres confining pressure, room temperature, of dry Yule Marble. By F. J. Turner and C. S. Ch'ih ... 887
— — in deformed Yule marble. By J. W. Handin and David Griggs ... 863
Facies in Carboniferous rocks of northern Alaska. By J. T. Dutro, Jr., A. L. Bowsher, Sr., and W. P. Brosgé 1434

— relationships of reefs. By P. E. Cloud, Jr. ... 1499
FAHEY, J. J. (With V. T. ALLEN): Salite and actinolite at Iron Mountain, Missouri ... 1420
— (With L. G. BERRY and E. H. BAILEY): Robinsonite, a new lead antimony sulphide ... 1423
Faulted Paleocene of Ridge Basin, California. By R. W. Webb ... 1488
Fish Creek phacolith, northwestern New York. By Richard Dietrich ... 1430
FISHER, D. J.: New universal microscope goniometer ... 1437
FISHER, R. L. (With F. P. SHEPARD and D. L. INMAN): Marine beaches of the United States ... 1477
FITZHUGH, E. F., JR.: Iron ore at Bomi Hill, Liberia ... 1437
FLAGLER, C. W.: Petroleum prospects of Denmark ... 1550
Flattop re-examined. By C. J. Hares ... 1448
FLAWN, P. T.: Geology of the Carrizo Mountain schist, Texas ... 1437
Flexures of glacial upwarping in New England. By R. J. Lougee ... 1556
FLINT, D. E.: Okinawa and the Ryuku arc ... 1438
FLINT, R. F.: Possible European correlatives of Wisconsin glacial substages ... 1438
FLOWER, R. H.: Problems in endoceroid classification ... 1439
FOGARTY, C. F.: Pediments of the Golden-Morrison area, Jefferson County, Colorado ... 1534
FOIS, VITTORIO: Ripalta Field, a typical gas field of Po Valley, Northern Italy ... 1550
FOOSE, R. M.: Ground-water behavior in the Hershey Valley, Pennsylvania ... 1439
Foraminifera in North Atlantic deep sea cores. By F. B Phleger, F. L. Parker, and J. F. Peirson ... 1470
— of the "Sidney," Nortonville, and Kellogg shales. By C. V. Fulmer ... 1522
FOREMAN, FRED: Study of some Bermuda rocks ... 1297
Fort Sage Mountain, California, earthquake of December 14, 1950. By V. P. Gianella ... 1502
Fossil fresh-water mollusks and ecological interpretations. By Teng-Chien Yen ... 1375
FOSTER, H. L., and MASON, A. C.: 1950 and 1951 eruptions of Mihara Yama, O Shima Volcano, Japan ... 1439
FOSTER, M. D. (With C. S. Ross): Studies of minerals in dunites and in olivine-rich inclusions in basaltic rocks ... 1473
Foundation and abutment treatment—McNary Dam, Oregon and Washington. By J. D. Arthur ... 1496
— problems, Folsom Dam project, California. By R. C. Treasher and M. F. Rose ... 1513
— —, San Francisco Bay, California. By P. D. Trask and J. W. Rolston ... 1079
Four series of alkali feldspars. By O. F. Tuttle and N. L. Bowen ... 1486
FOX, P. P.: Engineering geology in Brazil ... 1440
†FREDERICKSON, A. F.: Mechanism of weathering—a reply 1411
Frequency distributions as a test for theories of zoning in plagioclase. By Clyde Wahrhaftig ... 1520
FRIEDMAN, G. M.: Hoegbomite ... 1440
Frilled Atrypas from the Devonian of Manitoba. By E. I. Leith ... 1459
FRONDEL, J. W.: Dating the Wissahickon schist at Philadelphia, Pennsylvania ... 1550
Frost action on excavated slopes in Niobrara chalk, Fort Randall Dam, South Dakota. By J. A. Trantina ... 1543
FRUEH, A. J., JR.: Role of the hydrogen bond in the formation of some metastable phases ... 1441
FRYE, J. C. (With A. R. LEONARD): Problems of alluvial-terrace mapping for the engineering geologist ... 1460
FULMER, C. V.: Foraminifera of the "Sidney," Nortonville, and Kellogg shales ... 1522
FURCRON, A. S.: Stratigraphy and structure of Georgia crystalline rocks ... 1551
Further biogeochemical data from the San Manuel Copper Deposit, Pinal County, Arizona. By H. V. Warren, R. E. Delavault, and R. I. Irish ... 919; 1520
— improvements in a capacity-transducer seismograph. By Hugo Benioff ... 1525
— observations of the T phase. By Maurice Ewing, Frank Press, and J. L. Worzel ... 1527
Fusulinidae in the Pennsylvanian of Ohio. By Pauline Smyth ... 1481

GABELMAN, J. W.: Structure and origin of the northern Sangre de Cristo Mountains, Colorado ... 1534
GAINES, R. V.: Mineralogy and structure of the Luzonite-Famatinite series ... 1441
GARDINER, LYNN (With J. W. GRUNER and C. C. TOWLE): Uranium mineralization in Todilto limestone near Grants, McKinley County, New Mexico ... 1445
GARNER, H. F. (With A. K. Miller): Lower Mississippian nautiloid cephalopods of Michigan ... 1464
GAULT, H. R. (With C. A. WARMKESSEL): Chemical characteristics of the Jacksonburg formation ... 1487
GEISSE, ELAINE: Syenites and nepheline syenites of Stettin, Marathon County, Wisconsin ... 1442
Geogenic Jersey. By A. K. Botts ... 1547
Geographic research program of the Office of Naval Research. By L. O. Quam ... 1559
— work in New York State government. By D. H. Weeks, Jr. ... 1561
— — of Arnold Guyot. By R. L. Anstey ... 1545
Geologic history of sea water: an attempt to state the problem. By W. W. Rubey ... 1111
— problems in design and construction of highways. By O. L. Stokstad ... 1483
— — — — — — — — in Virginia. By W. T. Parrott ... 1468
— setting of the Mountain Pass bastnaesite deposits, San Bernardino County, California. By J. C. Olson and W. N. Sharp ... 1467
Geological conditions of oil occurrence in Middle East fields. By N. E. Baker and F. R. S. Henson ... 1546
— foundation of exploration for petroleum in Japan. By C. M. Pollock ... 1559
— problems in highway design and construction in Kansas. By S. E. Horner and E. Dobrovolny ... 1451
— projections under volcanic cover, East Tintic, Utah. By P. D. Proctor ... 1470
Geology, Applications to engineering problems, San Francisco Bay, California. By P. D. Trask and J. W. Rolston ... 1079
— and oil fields of Brazil. By E. F. Taylor ... 1561
— in highway design and construction: the Pennsylvania Turnpike's western extension. By A. B. Cleaves ... 1429
— of Apex stock, Gilpin County, Colorado. By S. L. Moore and C. D. Rinehart ... 1540
— — Carrizo Mountain schist, Texas. By P. T. Flawn ... 1437
— — central Middle Park, Colorado. By O. W. Tollefson ... 1542
— — coastal Ecuador with reference to petroleum deposits. By Cecil Hagen ... 1552
— — Glen Canyon group between Lees Ferry and Tuba City, Arizona. By J. T. Callahan ... 1498
— — Precambrian area near Rochford, South Dakota. By R. W. Lane and J. M. Wilson ... 1538
— — Saipan, Mariana Islands. By P. E. Cloud, Jr.; R. G. Schmidt; and H. W. Burke ... 1499
— — Santa Ysabel quadrangle, California. By Richard Merriam ... 1508
— — the Sioux formation. By Brewster Baldwin ... 1532
Geophysical investigations in the emerged and submerged Atlantic Coastal Plain. Part VI: The Long Island area. By J. E. Oliver and C. L. Drake ... 1287
GIANELLA, V. P.: Fort Sage Mountain, California, earthquake of December 14, 1950 ... 1502
— (With E. R. LARSON): Ammonoid from Lake Tahoe ... 1522
Giant playa-crack polygons in New Mexico compared with Arctic tundra-crack polygons. By M. M. Knechtel ... 1455

GILBERT, C. M.: Laumontite from Anchor Bay, Mendocino County, California 1517
GILL, J. E.: Original crust in the Canadian Shield area ... 1442
GIVENS, D. B., and BECK, C. W.: New basic copper phosphate mineral from Santa Rita, New Mexico 1442
Glacial clays in Steep Rock Lake, Ontario, Canada. By Ernst Antevs 1223
— geology
Accumulation and ablation of Seward-Malaspina glacier system. By R. P. Sharp 725
Illinoian and Wisconsin drift of the southern part of the Grand River lobe in eastern Ohio. By G. W. White 967
— Lake Souris, North Dakota. By R. W. Lemke 1459
— waters in Catskill (New York) area. By G. H. Chadwick 1549
GLASS, H. D., and SIEVER, RAYMOND: Occurrence of dolomites in the Pennsylvanian of Illinois 1443
Glomeroblastic aggregates as an intermediate stage of crystalloblastic growth. By G. E. Goodspeed 1518
GOLDSMITH, J. R. (With FRITZ LAVES): On the superstructure in anorthite 1458
GOLDSTEIN, AUGUST, JR., and HENDRICKS, T. A.: Siliceous sediments of Ouachita facies in Oklahoma 1443
GOLDTHWAIT, R. P.: Deglaciation of north-central Baffin Island 1443
GOODE, H. D. (With T. S. LOVERING): Relation of factors affecting ground and rock temperature at shallow depths 1461
GOODSPEED, G. E.: Glomeroblastic aggregates as an intermediate stage of crystalloblastic growth 1518
GOSMAN, R. F. (With F. S. HONKALA and B. K. REPLOGLE): Stratigraphy of the Phosphoria formation, Centennial Range, southwestern Montana 1537
GOTT, G. B.; WYANT, D. G.; and BERONI, E. P.: Uranium in black shales, lignites, and limestones in the United States 1535
GRAF, D. L.: Variations in differential thermal curves of low-iron dolomites 1444
GRAHAM, A. R., and KAIMAN, S.: Aurostibite—a new mineral in the pyrite group 1444
Grand Canyon Algonkian of Arizona, Nankoweap group of. By C. E. Van Gundy 953
Grand Coulee, Washington. Mold of a rhinoceros in basalt, lower. By W. M. Chappell, J. W. Durham, and D. E. Savage 907
Grand River lobe in eastern Ohio, Illinoian and Wisconsin drift of the southern part. By G. W. White 967
GRANGER, H. E. (With D. G. WYANT and E. P. BERONI): Some uranium deposits in sandstone 1544
Granitic magma and the geologic history of sea water. By W. W. Rubey 1111
Graphs for visual comparison of several factors in heat exchange near Barrow, Alaska. By R. F. Black 1546
GREEN, MORTON: Pleistocene of sub-Recent *Equus* in Rapid City, South Dakota 1535
GREENWOOD, ROBERT: Younger intrusive rocks of Plateau Province, Nigeria, compared with the alkalic rocks of New England 1151
GRIES, J. P., and BERG, D. A.: Problems of the Minnelusa formation in the Black Hills 1535
GRIFFITHS, J. C.: Size and sorting in sediments 1551
GRIGGS, DAVID, and MILLER, W. B.: Deformation of Yule marble: Part I—Compression and extension experiments on dry Yule marble at 10,000 atmospheres confining pressure, room temperature 853
— *et al.*: Deformation of the Yule marble: Part IV—Effects at 150°C 1385
— (With J. W. HANDIN): Deformation of Yule marble: Part II—Predicted fabric changes 863
GRIM, R. E.; BRADLEY, W. F.; and WHITE, W. A.: Petrology of the Paleozoic shales of Illinois 1445
Ground-water behavior in the Hershey Valley, Pennsylvania. By R. M. Foose 1439
— contamination by saline thermal waters. By R. E. Marsell 1506
— problems in Pennsylvania. By S. H. Cathcart 1548
GROUT, F. F., *et al.*: Precambrian stratigraphy of Minnesota 1017
GRUNER, J. W.; TOWLE, C. C.; and GARDINER, LYNN: Uranium mineralization in Todilto limestone near Grants, McKinley County, New Mexico 1445
— (With F. F. GROUT *et al.*): Precambrian stratigraphy of Minnesota 1017
GRYC, GEORGE (With T. G. Payne): Alaska petroleum in relation to geologic history 1557
GUDE, A. J., III (With FREDERICK STUGARD, JR. and D. G. WYANT): Secondary uranium deposits in the United States 1542
GUENNEL, G. K.: Spore analyses applied to a coal correlation problem in southern Indiana 1445
Gulf of Alaska, Submarine geology of. By H. W. Menard and R. S. Dietz 1263
Gullied submarine slopes off Southern California. By E. C. Buffington 1497
GUTENBERG, B.: Surface waves recorded by a Benioff vectorial seismograph 1527
—: Travel times of waves from artificial explosions 1528

HACQUEBARD, P. A.: Opaque matter in coal 1446
HADLEY, J. B.: Origin of some plutonic granitic gneisses in the northern and southern Appalachians 1552
HAGEN, CECIL: Geology of coastal Ecuador with reference to petroleum deposits 1552
HAM, W. E.: Dolomite in the Arbuckle limestone, Arbuckle Mountains, Oklahoma 1446
HAMBLETON, W. W.: Practical significance of the petrographic characteristics of two Kansas coal beds ... 1447
HAMILTON, E. L.: Sunken islands of the mid-Pacific mountains 1502
HAMILTON, W. B.: Variations in granitic rocks of the Huntington Lake area of the Sierra Nevada, California 1447
HAMMOND, PAUL: Allard Lake ilmenite deposits 1448
HANDIN, J. W., and GRIGGS, DAVID: Deformation of Yule marble: Part II—Predicted fabric changes 863
HANSON, A. M.: "Dry Creek formation" in southwestern Montana 1536
HARDER, J. O.: Vein quartz in the Homestake ore body ... 1536
HARES, C. J.: Flattop re-examined 1448
HARRINGTON, J. W.: Elements of a plan for research in mountain building 1449
HARRISON, J. V.: Collapse structure 1449
Hawaiian swell, deep, and arch and the subsidence of the Hawaiian Islands. By R. S. Dietz and H. W. Menard 1431
HAZZARD, J. C.: Revision of Devonian and Carboniferous sections, Nopah Range, Inyo County, California 1503
†HEEZEN, B. C.; EWING, MAURICE; and ERICSON, D. B.: Submarine topography in the North Atlantic 1407
†—(With D. B. ERICSON and MAURICE EWING): Deep-sea sands and submarine canyons 961
HEINRICH, E. WM.: Petrology of the Franklin-Sylva pegmatite district, North Carolina 1449
Helicoprion from Elks County, Nevada. By E. R. Larson and J. B. Scott 1523
HENDRICKS, T. A. (With AUGUST GOLDSTEIN, JR.): Siliceous sediments of Ouachita facies in Oklahoma .. 1443
HENSON, F. R. S. (With N. E. BAKER): Geological conditions of oil occurrence in Middle East fields 1546
HERPERS, HENRY: Marcellus formation in New Jersey 1553
HERZ, NORMAN: Petrology of the Baltimore gabbro, Maryland 979

HEWITT, D. F.: Sedimentation and stratigraphy of the Timiskaming series, Kirkland Lake, Ontario 1450
HIESTAND, T. C.: Proposed field conference for 1954: Baker, Oregon, to Rapid City, South Dakota 1536
Hoegbomite. By G. M. Friedman 1440
HOLSER, W. T., *et al.*: Notes on the geochemistry of beryllium 1450
HONKALA, F. S.; REPLOGLE, B. K.; and GOSMAN, R. F.: Stratigraphy of the Phosphoria formation, Centennial Range, southwestern Montana 1537
HOPPIN, R. A.: Palen Mountains gypsum deposit, Riverside County, California 1518
HORBERG, LELAND: Pleistocene drift sheets in the Lethbridge region, Alberta, Canada 1553
HORNER, S. E., and DOBROVOLNY, E.: Geological problems in highway design and construction in Kansas 1451
HOWARD, A. D. (With R. B. COLTON): Driftless areas in northeastern Montana 1429
HOYLMAN, H. W.: Use of geophysical methods in the search for reefs 1503
HUDSON, F. S.: Mount Lincoln-Castle Peak area, Sierra Nevada, California 931
Humisol. By G. F. Carter and V. P. Sokoloff 1548
Hungry Run sandstone member (new name). By Wallace de Witt, Jr. 1347
Hurlbutite, $CaBe_2(PO_4)_2$, a new mineral. By M. E. Mrose 1464
HUTTON, C. E.: Uranoan thorite and thorian monazite from blacksand paystreaks, San Mateo County, California 1518
Hypsometric function for small drainage basins. By A. N. Strahler 1561

Identification of features named by Amundsen in the Queen Maud Range. By H. E. Saunders 1560
Igneous rock
Mold of rhinoceros in basalt, lower Grand Coulee, Washington. By W. M. Chappell, J. W. Durham, and D. E. Savage 907
Illinoian and Wisconsin drift of the southern part of the Grand River lobe in eastern Ohio. By G. W. White 967
Influence of minor geologic structures on dam construction. By E. B. Burwell, Jr. 1427
Infolded mid-Ordovician limestone on Precambrian north of Peekskill, New York, and its bearing on the region's orogeny. By W. H. Bucher 1426
INGHRAM, M. C. (With HARRISON BROWN *et al.*): Isotopic composition of lead and the ages of minerals in a Precambrian granite 1426
Initial motion of the first longitudinal earthquake wave recorded at Pasadena and Huancayo. By Markus Båth 1525
INMAN, D. L. (With F. P. SHEPARD and R. L. FISHER): Marine beaches of the United States 1477
Insect fossils in onyx marble, and modern entrapment in calcite waters. By W. D. Pierce 1523
Internal structure of the Sinbad Valley-Fisher Valley salt anticline, Colorado and Utah. By E. M. Shoemaker 1478
Interrelation of structure and Pennsylvanian sedimentation in Central Illinois. By E. P. Du Bois 1433
Intrusive rocks of Plateau Province, Nigeria, compared with the alkalic rocks of New England, Younger. By Robert Greenwood 1151
Ionic radii of the elements. By L. H. Ahrens 1419
IRELAND, H. A.: Surface tension as an effective factor in gradation 1451
IRISH, R. I. (With H. V. WARREN and R. E. DELAVAULT): Further biogeochemical data from the San Manuel copper deposit, Pinal County, Arizona 919; 1478
Iron ore at Bomi Hill, Liberia. By E. F. Fitzhugh, Jr. 1437
Iron-ore deposits of New Quebec and Labrador. By J. A. Retty and A. E. Moss 1471
IRWIN, W. P. (With R. H. JAHNS): Vasquez series in the upper Tick Canyon area, Los Angeles County, California 1504
Isostatic considerations in the problem of the geologic history of sea water. By W. W. Rubey 1111
Isotopic composition of lead and the ages of minerals in a Precambrian granite. By Harrison Brown, M. C. Inghram, E. S. Larsen, Jr., Clair Patterson, and George Tilton 1426
IVES, R. L.: Pleistocene valley sediments of the Dugway area, Utah 781

JACKMAN, A. H.: Landforms near Big Delta, Alaska 1553
JACKSON, R. L.: Stratal relationships of the Supai formation of central Arizona 1504
JAHNS, R. H., and IRWIN, W. P.: Vasquez series in the upper Tick Canyon area, Los Angeles County, California 1504
JAMES, H. L.: Sedimentary facies of the Lake Superior iron-bearing formation, and their relation to volcanism and geosynclinal development 1482
James River synclinorium and related structure in the western Virginia Piedmont. By W. R. Brown 1547
Jellyfish medusa in the Nankoweap sediments, Basalt Canyon, Arizona. By C. E. Van Gundy 953
JENSEN, F. S.: Bedrock deformation of late Quaternary age at Tiger Butte, northeastern Montana 1452
—: Disconformity at the contact of the Fox Hills sandstone and Hell Creek formation in northeastern Montana 1453
JENSEN, R. S. (With R. W. LEMKE and J. H. SMITH): Linear crevasse fillings, outwash channels, and other similarly oriented glacial features in north-central North Dakota 1460
JOHNSON, M. E., and RICHARDS, H. G.: Stratigraphy of the coastal plain of New Jersey 1554
JONES, W. F., and LUCKE, J. B.: Evolution of Nantucket shore lines 1453

KAIMAN, S. (With A. R. Graham): Aurostibite—a new mineral in the pyrite group 1444
KAISER, E. P., and PAGE, L. R.: Distribution of uranium deposits in the United States 1537
KALLIOKOSKI, J.: Structure of the Kisseynew gneisses in the Weldon Bay-Sherridon region, Manitoba 1453
KAY, MARSHALL: Taconic thrust in Sudbury, Vermont 1554
—: Volcanic rocks in geosynclines 1454
KEENMON, K. A.; KUPSCH, W. O.; and SCHOLTEN, ROBERT: Tectonic history of the Lima region, southwestern Montana and adjacent Idaho 1454
KING, L. H. (With W. L. WHITEHEAD): Vacuum differential thermal analysis of coal 1489
KING, P. B.: Relation of the folded Appalachians to the crystalline Appalachians in the light of Great Smoky Mountains geology 1554
KING, R. U., and MOORE, F. B.: Pitchblende deposits in the United States 1537
KIRK, M. V., and MACINTYRE, J. R.: Cretaceous deposits of the Punta San Isidro area, Baja California 1505
KJELLESVIG-WAERING, E. N. (With K. E. CASTER): Concerning the Eurypterid *Megalograptus*, an Upper Ordovician anachronism 1428
KLEINPELL, R. M., and ARNOLD, Z. M.: Cretaceous in the Philippines 1455
KNECHTEL, M. M.: Giant playa-crack polygons in New Mexico compared with Arctic tundra-crack polygons 1455
KOHANOWSKI, N. N.: Secondary enrichment in Bolivian tungsten deposits 1538

KOSANKE, R. M.: Chemical analyses of constituents of clarain ... 1455
KULP, J. L.: Age determinations by carbon 14 ... 1456
—: Natural radiocarbon measurements ... 1555
— (With H. L. VOLCHOK): Radon and thick source alpha determinations on deep-sea cores ... 1487
KUPFER, D. H.: Thrusting and chaos structure in the Silurian Hills, San Bernardino County, California ... 1456
KUPSCH, W. O. (With K. A. KEENMON and ROBERT SCHOLTEN): Tectonic history of the Lima region, southwestern Montana and adjacent Idaho ... 1454

LA ROCQUE, A.: Molluscan fauna of the Flagstaff formation, Central Utah ... 1457
LACKEY, E. E.: Climatic probabilities in Iran ... 1555
Lake Bonneville
Pleistocene valley sediments of the Dugway area, Utah. By R. L. Ives ... 781
Lake Johnston (new name), Steep Rock Lake region, Ontario. By Ernst Antevs ... 1223
LAMAR, J. E., and SHRODE, R. S.: Water-soluble salts in limestones and dolomites ... 1456
LANDES, K. K.: Origin of thick-bedded salt deposits ... 1457
—: Our shrinking globe ... 1555
Landforms near Big Delta, Alaska. By A. H. Jackman ... 1553
Landslide caused by over-irrigation near Cambridge, Washington County, Idaho. By V. E. Scheid ... 1511
LANE, R. W., and WILSON, J. M.: Geology of a Precambrian area near Rochford, South Dakota ... 1538
Laramide structures in the Parowan Gap area, southwestern Utah, and their relation to the Colorado Plateau-Basin and Range boundary. By R. L. Threet ... 1513
Large thrusts in northern Cascades of Washington. By Peter Misch ... 1508
LARSEN, E. S., JR. (With HARRISON BROWN *et al.*): Isotopic composition of lead and the ages of minerals in a Precambrian granite ... 1426
LARSON, E. R., and GIANELLA, V. P.: Ammonoid from Lake Tahoe ... 1522
— and SCOTT, J. B.: Helicoprion from Elko County, Nevada ... 1523
Late Paleozoic reef sequences in West Texas. By J. E. Adams ... 1495
— Wisconsin terraces and soils near St. Louis, Missouri. By L. C. Peltier ... 1558
Laumontite from Anchor Bay, Mendocino County, California. By C. M. Gilbert ... 1517
LAVES, FRITZ, and GOLDSMITH, J. R.: On the superstructure in anorthite ... 1458
"Leesport" and "Annville" formations of Pennsylvania. By C. E. Prouty ... 1471
LEGRAND, H. E.: Solution depressions in diorite in North Carolina ... 1458
—: Streamlining of the Carolina bays ... 1459
LEIGHTON, F. B.: Ogives of the East Twin Glacier, Alaska—their nature and origin ... 1505
LEITH, E. I.: Frilled Atrypas from the Devonian of Manitoba ... 1459
— (With GEORGE MACAULEY): Winnipeg formation of Manitoba ... 1461
LEMISH, JOHN (With T. S. LOVERING *et al.*): Upper Ordovician, Silurian, and Devonian stratigraphy of the Tintic Mountains, Utah ... 1505
LEMKE, R. W.: Glacial Lake Souris, North Dakota ... 1459
—; JENSEN, R. S.; and SMITH, J. H.: Linear crevasse fillings, outwash channels, and other similarly oriented glacial features in north-central North Dakota ... 1460
LEONARD, A. R., and FRYE, J. C.: Problems of alluvial terrace mapping for the engineering geologist ... 1460
LEROY, L. W.: Space-time concept in geology ... 1539
Linear crevasse fillings, outwash channels, and other similarly oriented glacial features in north-central North Dakota. By R. W. Lemke, F. S. Jensen, and J. H. Smith ... 1460
Localization of sodium sulfate deposits in northeastern Montana and northwestern North Dakota. By I. J. Witkind ... 1544
LOGAN, J. A.: Origin of boron in the ground waters of California ... 1505
Long Island area
Geophysical investigations in the emerged and submerged Atlantic Coastal Plain. Part VI. By J. E. Oliver and C. L. Drake ... 1287
LOUGEE, R. J.: Chronology of post-glacial time ... 1556
—: Flexures of glacial upwarping in New England ... 1556
LOVERING, T. S., and GOODE, H. D.: Relation of factors affecting ground and rock temperature at shallow depths ... 1461
— *et al.*: Upper Ordovician, Silurian, and Devonian stratigraphy of the Tintic Mountains, Utah ... 1505
LOWENSTAM, H. A.: Analyses of fossil reef-type facies ... 1506
Lower Mississippian nautiloid cephalopods of Michigan. By A. K. Miller and H. F. Garner ... 1464
LUCKE, J. B. (With W. F. JONES): Evolution of Nantucket shore lines ... 1453

MACAULEY, GEORGE, and LEITH, E. I.: Winnipeg formation of Manitoba ... 1461
MACDONALD, J. R.: Pathological vertebrates from South Dakota ... 1539
MACINTYRE, J. R. (With M. V. KIRK): Cretaceous deposits of the Punta San Isidro area, Baja California ... 1505
Magnetic susceptibility of chromite from Montana and its relation to other physical and chemical properties. By J. W. Peoples and G. P. Eaton ... 1469
MANDRA, Y. T.: Preliminary stratigraphic report of some California Eocene silicoflagellates ... 1523
Marble, deformation of Yule. By David Griggs and W. B. Miller ... 853
—, — — —. By D. T. Griggs, F. J. Turner, Iris Borg, and John Sosoka ... 1385
—, — — —. By J. W. Handin and David Griggs ... 863
—, — — —. By F. J. Turner and C. S. Ch'ih ... 887
Marcellus formation in New Jersey. By Henry Herpers ... 1553
Margarite-ephesite series; theory versus fact. By W. T. Schaller and M. K. Carron ... 1476
Marine beaches of the United States. By F. P. Shepard, D. L. Inman, and R. L. Fisher ... 1477
Marl facies of the lower Pierre in south-central South Dakota. By R. E. Stevenson ... 1542
MARPLE, M. F.: Microfauna of the Pottsville series in Ohio ... 1462
MARSELL, R. D.: Ground-water contamination by saline thermal waters ... 1506
Maryland
Petrology of the Baltimore gabbro. By Norman Herz ... 979
Structural relations of Cretaceous and Tertiary formations in. By N. H. Darton ... 745
Mascall Miocene fauna and related assemblages from Oregon. By Theodore Downs ... 1432
MASON, A. C. (With H. L. FOSTER): 1950 and 1951 eruptions of Mihara Yama, O Shima Volcano, Japan ... 1439
Massachusetts
Ocean-bottom photographs of the neritic and bathyal environment south of Cape Cod. By John Northrop ... 1381
MAUREE, RUSSELL (With FORBES ROBERTSON): Evidence bearing on the consanguinity of Missouri and Oklahoma Precambrian igneous rocks ... 1541
MAYNARD, J. E. (With E. T. APPEL *et al.*): Possible diatreme in Syracuse, New York ... 1421

McCARTNEY, J. T.: Study of the Seyler theory of coal reflectance ... 1462
McCONNELL, DUNCAN: Problem of the carbonate apatites, IV—structural substitutions involving CO_3 and OH ... 1463
McINTYRE, J. M. (With F. G. WELLS AND G. W. WALKER): Pre-Cretaceous stratigraphy of the northern Klamath Mountains ... 1514
McKINSTRY, HUGH: Structure and copper mineralization at the Elizabeth Mine, Vermont ... 1463
McNAUGHTON, D. A.: Dynamic role of dilatancy in the migration and accumulation of oil in metamorphic rocks: a hypothesis ... 1507
MEARS, BRAINERD, JR.: "Reverse drag" on high-angle faults in Oak Creek Canyon, Arizona ... 1539
Mechanism of earthquake generation. By Hugo Benioff ... 1526
†— —weathering—a reply. By A. F. Frederickson ... 1411
Medusa in the Nankoweap sediments, Basalt Canyon, Arizona. By C. E. Van Gundy ... 953
Megatectonics
Origin of compressional mountains and associated phenomena. By J. L. Rich ... 1179
Mehrten formation erosional interval. By G. H. Curtis ... 1500
MENARD, H. W., and DIETZ, R. S.: Mendocino submarine escarpment ... 1507
— — —: Submarine geology of the Gulf of Alaska ... 1263
— (With R. S. DIETZ): Hawaiian swell, deep, and arch and the subsidence of the Hawaiian Islands ... 1431
— (— —): Origin of the shelf-break ... 1501
Mendocino submarine escarpment. By H. W. Menard and R. S. Dietz ... 1507
MERRIAM, C. W.: Silurian quartzites of the Inyo Mountains, California ... 1508
MERRIAM, R. H.: Geology of the Santa Ysabel quadrangle, California ... 1508
— (With O. L. BANDY): Test wall microstructure as a basis for separating *Nonion* and *Elphidium* ... 1521
MERRILL, W. M.: Replacement of the Middle Kittanning coal by interfingering clastics in southeastern Ohio ... 1463
— (With H. R. WANLESS): Evidence of eustatic change in sea level in the Pennsylvanian of the southwestern United States ... 1487
Microfauna of the Pottsville series in Ohio. By M. F. Marple ... 1462
Microscopic study of an inclusion in the Idaho batholith. By W. R. Wagner ... 1543
MILLER, A. K., and GARNER, H. F.: Lower Mississippian nautiloid cephalopods of Michigan ... 1464
MILLER, E. WILLARD: Need for establishment of a national and international mineral policy ... 1556
MILLER, W. B. (With DAVID GRIGGS): Deformation of Yule marble: Part I—Compression and extension experiments on dry Yule marble at 10,000 atmospheres confining pressure, room temperature ... 853
MILTON, C. (With J. M. AXELROD *et al.*): Phosphate mineralization at Bomi Hills and Bambuta, Liberia, West Africa ... 1421
Mineralogy, petrography, and petrology of the K-bentonites. By C. E. Weaver and T. F. Bates ... 1488
— and structure of the Luzonite-Famatinite series. By R. V. Gaines ... 1441
— of Baltimore gabbro, Maryland. By Norman Herz ... 979
— — younger intrusive rocks of Plateau Province, Nigeria. By Robert Greenwood ... 1151
MIMICK, J. N.: Tertiary stratigraphy of southeastern Wyoming and northeastern Colorado ... 1540
Minnesota, Precambrian stratigraphy of. By F. F. Grout, J. W. Gruner, G. M. Schwartz, and G. A. Thiel ... 1017
MISCH, PETER: Large thrusts in northern Cascades of Washington ... 1508
Mississippian scolecodonts near Chardon, Ohio. By A. S. Bowen ... 1424
Mode of growth in some echinoids. By J. W. Durham ... 1434
Modern fold in Texas. By A. A. Socolow ... 1481
Mold of a rhinoceros in basalt, lower Grand Coulee, Washington. By W. M. Chappell, J. W. Durham, and D. E. Savage ... 907
Molluscan fauna of the Flagstaff formation, Central Utah. By A. La Rocque ... 1457
Mollusks and ecological interpretations, Fresh-water. By Teng-Chien Yen ... 1375
Monterey sea valley, Stream gradients and. By A. O. Woodford ... 799
MOORE, F. B. (With R. U. KING): Pitchblende deposits in the United States ... 1537
MOORE, S. L., and RINEHART, C. D.: Geology of the Apex stock, Gilpin County, Colorado ... 1540
Morphology and origin of large-scale and small-scale pediment forms compared. By K. G. Smith ... 1480
MORRIS, H. T. (With T. S. LOVERING *et al.*): Upper Ordovician, Silurian, and Devonian stratigraphy of the Tintic Mountains, Utah ... 1505
MOSS, A. E. (With J. A. RETTY): Iron-ore deposits of New Quebec and Labrador ... 1471
Mount Lincoln—Castle Peak area, Sierra Nevada, California. By F. S. Hudson ... 931
Mountains, origin of. By J. L. Rich ... 1179
MROSE, M. E.: Hurlbutite, $CaBe_2(PO_4)_2$, a new mineral ... 1464
MURDOCH, JOSEPH: Phosphate minerals from Brazil: progress report ... 1519
—: Unit cell of hydromagnesite ... 1465
MURRAY, H. H.: Observations on the structures of some kaolinites and dehydrated halloysite ... 1465

Nankoweap group (new name) **of the Grand Canyon Algonkian of Arizona.** By C. E. Van Gundy ... 953
NANZ, R. H., JR.: Chemical composition of North American Precambrian slates ... 1466
Natural radiocarbon measurements. By J. L. Kulp ... 1555
Nautiloid *Rayonnoceras* in California. By J. H. Peck, Jr. 1523
Need for establishment of a national and international mineral policy. By E. Willard Miller ... 1556
Nephrite in Marin County, California. By C. W. Chesterman ... 1517
NEUERBURG, G. J.: Evidence of a major fault truncating the eastern end of the Santa Monica Mountains, California ... 1509
New basic copper phosphate mineral from Santa Rita, New Mexico. By D. B. Givens and C. W. Beck ... 1442
—determinations of geologic age by the thermoluminescence method. By E. J. Zeller ... 1493
New England, Younger intrusive rocks of Plateau Province, Nigeria, compared with the alkalic rocks of. By Robert Greenwood ... 1151
New mechanical twinning in calcite. By E. C. Robertson ... 1472
— oil developments in Mexico in relation to their regional setting. By Manuel Alvarez, Jr. ... 1545
— tektite areas in Texas. By V. E. Barnes ... 1422
— universal microscope goniometer. By D. J. Fisher ... 1437
NEWELL, N. D.: Organic reefs and submarine dunes of oölite sand around Tongue of the Ocean, Bahamas ... 1466
Nigeria
Younger intrusive rocks of Plateau Province, compared with the alkalic rocks of New England. By Robert Greenwood ... 1151
1950 and 1951 eruptions of Mihara Yama, O Shima Volcano, Japan. By H. L. Foster and A. C. Mason ... 1439
NORTHROP, JOHN: Ocean-bottom photographs of the neritic and bathyal environment south of Cape Cod, Massachusetts ... 1381
Notes on the geochemistry of beryllium. By W. T. Holser, L. A. Warner, V. R. Wilmarth, and E. N. Cameron ... 1450

NUFFIELD, E. W. (With E. J. BROOKER): Studies of radioactive compounds: IV—Pitchblende from Lake Athabaska ... *1425*

OAKESHOTT, G. B.: San Gabriel and related faults in the western San Gabriel Mountains, California ... *1509*
Observations on the structures of some kaolinites and dehydrated haloysite. By H. H. Murray ... *1465*
Ocean-bottom photographs of the neritic and bathyal environment south of Cape Cod, Massachusetts. By John Northrop ... 1381
Oceanography
  Ocean-bottom photographs of the neritic and bathyal environment south of Cape Cod, Massachusetts. By John Northrop ... 1381
Occurrence of dolomites in the Pennsylvanian of Illinois. By H. D. Glass and Raymond Siever ... *1443*
O'DONNELL, H. J. (With B. C. PARKS): Petrographic analysis of column samples by combined thin-section and broken-coal method with results on a sample of No. 6 coal from St. Clair County, Illinois ... *1467*
OFFICER, C. B., JR.; EWING, MAURICE; and WUENSCHEL, P. C.: Seismic-refraction measurements in the Atlantic Basin, Part II ... *1528*
Ogives of the East Twin Glacier, Alaska—their nature and origin. by F. B. Leighton ... *1505*
OGLE, B. A.: Wildcat group in the Eel River area, Humboldt County, California ... *1510*
OGLE, B. A. (With D. E. SAVAGE and R. S. CREELY): Subdivision of vertebrate-bearing nonmarine Pliocene rocks in west-central Contra Costa County, California ... *1511*
Ohio
  Illinoian and Wisconsin drift of the southern part of the Grand River lobe in eastern Ohio. By G. W. White ... 967
  Stratigraphy of the Berea sandstone and associated rocks in northeastern. By Wallace de Witt, Jr. ... 1347
Oil possibilities of Australia. By Frank Reeves ... *1559*
Okinawa and the Ryuku arc. By D. E. Flint ... *1438*
Older Precambrian structure in Arizona. By C. A. Anderson ... 1331
OLIVER, J. E., and DRAKE, C. L.: Geophysical investigations in the emerged and submerged Atlantic Coastal Plain. Part VI: The Long Island area ... 1287
OLSON, J. C., and SHARP, W. N.: Geologic setting of the Mountain Pass bastnaesite deposits, San Bernardino County, California ... *1467*
On the superstructure in anorthite. By Fritz Laves and J. R. Goldsmith ... *1458*
Ontario
  Glacial clays in Steep Rock Lake. By Ernst Antevs ... 1223
Opal cement in thick Tertiary eolian sandstone, Chuska Mountains, Arizona-New Mexico. By H. E. Wright, Jr. ... *1492*
Opaque matter in coal. By P. A. Hacquebard ... *1446*
Organic reefs and submarine dunes of oölite sand around Tongue of the Ocean, Bahamas. By N. D. Newell ... *1466*
Origin and evolution of hornblende-andesine amphibolites and kindred facies. By A. E. J. Engel and C. G. Engel *1435*
— of astragalus in the reptilian tarsus. By F. E. Peabody. *1469*
— — boron in the ground waters of California. By J. A. Logan ... *1505*
— — **compressional mountains and associated phenomena.** By J. L. Rich ... 1179
— — offshore bars. By S. L. Blanton, Jr. ... *1424*
— — porphyritic phase of the Sterling granite gneiss in Connecticut-Rhode Island. By R. M. Perhac ... *1469*
— — shelf-break. By R. S. Dietz and H. W. Menard ... *1501*
— — some plutonic granitic gneisses in the northern and southern Appalachians. By J. B. Hadley ... *1552*
— — thick-bedded salt deposits. By K. K. Landes ... *1457*
Original crust in the Canadian Shield area. By J. E. Gill ... *1442*
Orogenic cycle. By J. L. Rich ... 1179
OSBORN, E. F. (With D. M. ROY): The system $MgO—Al_2O_3—H_2O$ ... *1474*
— (With RUSTUM ROY): Phase equilibria in the system $Al_2O_3—SiO_2—H_2O$ ... *1474*
Our shrinking globe. By K. K. Landes ... *1555*
† **Outcrop of Payette formation along Snake River near Hagerman, Idaho.** By H. T. Stearns ... 1149

PAGE, L. R. (With E. P. KAISER): Distribution of uranium deposits in the United States ... *1537*
Palen Mountains gypsum deposit, Riverside County, California. By R. A. Hoppin ... *1518*
Paleochemistry of sea water. By W. W. Rubey ... 1111
Paleoecology
  Fossil fresh-water mollusks and ecological interpretations. By Teng-Chien Yen ... 1375
Paleontology
  Geologic history of sea water: an attempt to state the problem. By W. W. Rubey ... 1111
  Mold of a rhinoceros in basalt, lower Grand Coulee, Washington. By W. M. Chappell, J. W. Durham, and D. E. Savage ... 907
  Relation of fossils to environment. By Teng-Chien Yen ... 1375
PALMER, P. S.: Composition and structure of the depths of earth derived from meteorites ... *1557*
PARKER, F. L. (With F. B PHLEGER and J. F. PEIRSON): Foraminifera in North Atlantic deep sea cores ... *1470*
PARKS, B. C., and O'DONNELL, H. J.: Petrographic analysis of column samples by combined thin-section and broken-coal method with results on a sample of No. 6 coal from St. Clair County, Illinois ... *1467*
PARKS, J. M., JR., and SAUNDERS, D. F.: Age of mineralization: thermoluminescence and radioactivity of fluorite ... *1468*
PARROTT, W. T.: Geologic problems in design and construction of highways in Virginia ... *1468*
Pathological vertebrates from South Dakota. By J. R. Macdonald ... *1539*
PATTERSON, CLAIR (With HARRISON BROWN *et al.*): Isotopic composition of lead and the ages of minerals in a Precambrian granite ... *1426*
PAYNE, T. G., and GRYC, GEORGE: Alaska petroleum in relation to geologic history ... *1557*
PEABODY, F. E.: Origin of the astragalus in the reptilian tarsus ... *1469*
PECK, J. H., JR.: Nautiloid *Rayonnoceras* in California ... *1523*
Pediment broadening in South Dakota badlands. By C. L. Baker ... *1531*
Pediments of the Golden - Morrison area, Jefferson County, Colorado. By C. F. Fogarty ... *1534*
PEIRSON, J. F. (With F. B PHLEGER and F. L. PARKER): Foraminifera in North Atlantic deep sea cores ... *1470*
PELTIER, L. C.: Late Wisconsin terraces and soils near St. Louis, Missouri ... *1558*
Pennsylvania
  Stratigraphy of the Berea sandstone and associated rocks in northwestern. By Wallace de Witt, Jr. ... 1347
PEOPLES, J. W., and EATON, G. P.: Magnetic susceptibility of chromite from Montana and its relation to other physical and chemical properties ... *1469*
PERHAC, R. M.: Origin of the porphyritic phase of the Sterling granite gneiss in Connecticut-Rhode Island. *1469*
Permo-Pennsylvanian zeugogeosyncline of Colorado and northern New Mexico. By K. G. Brill, Jr. ... *1425*
Petrofabric analysis of Yule marble deformed. By D. T. Griggs, F. J. Turner, Iris Borg, and John Sosoka ... 1385
— — — — — — at 10,000 atmospheres confining pres-

sure, room temperature, dry. By F. J. Turner and C. S. Ch'ih ... 887
— — — column samples by combined thin-section and broken-coal method with results on a sample of No. 6 coal from St. Clair County, Illinois. By B. C. Parks and H. J. O'Donnell ... *1467*
Petrography of the Baltimore gabbro, Maryland. By Norman Herz ... 979
Petroleum exploration and development in France, 1950 and 1951. By J. Dupouy-Camet ... *1549*
— prospects of Denmark. By C. W. Flagler ... *1550*
Petrology
Some Bermuda rocks. By Fred Foreman ... 1297
— and structure of the Hebron gneiss, Connecticut. By J. M. Aitken ... *1545*
— **of Baltimore gabbro, Maryland.** By Norman Herz ... 979
— — Franklin-Sylva pegmatite district, North Carolina. By E. Wm. Heinrich ... *1449*
— — Guffey-Micanite region, Colorado. By J. E. Bever ... *1423*
— — Paleozoic shales of Illinois. By R. E. Grim, W. F. Bradley, and W. A. White ... *1445*
— — younger intrusive rocks of Plateau Province, Nigeria. By Robert Greenwood ... 1151
Péwé, T. L.: Recent history of Black Rapids glacier, Alaska ... *1558*
Phase equilibria in the System Al_2O_3—SiO_2—H_2O. By Rustum Roy and E. F. Osborn ... *1474*
Phleger, F. B; Parker, F. L.; and Peirson, J. F.: Foraminifera in North Atlantic deep sea cores ... *1470*
Phosphate mineralization at Bomi Hills and Bambuta, Liberia, West Africa. By J. M. Axelrod, M. K. Carron, C. Milton, and T. P. Thayer ... *1421*
— minerals from Brazil: a progress report. By Joseph Murdoch ... *1519*
Physiographic reconnaissance in Iraqi Kurdistan. By H. E. Wright, Jr. ... *1492*
Pierce, W. D.: Insect fossils in onyx marble, and modern entrapment in calcite waters ... *1523*
Pillow-lava structure in amphibolite. By H. B. Wood ... *1515*
Pinal County, Arizona, Further biogeochemical data from the San Manuel copper deposit. By H. V. Warren, R. E. Delavault, and R. I. Irish ... 919
Pincus, H. J.: Sedimentary processes along the south shore of Lake Erie, vicinity of Sandusky, Ohio ... *1558*
Pitchblende deposits in the United States. By R. U. King and F. B. Moore ... *1495*
Pleistocene drift sheets in the Lethbridge region, Alberta, Canada. By Leland Horberg ... *1553*
— geology of the Door Peninsula, Wisconsin. By F. T. Thwaites and Kenneth Bertrand ... *1485*
— in western South Dakota. By C. L. Baker ... *1531*
— or sub-Recent *Equus* in Rapid City, South Dakota. By Morton Green ... *1535*
— stratigraphy in northeastern Ohio. By G. W. White ... *1489*
— **valley sediments of the Dugway area, Utah.** By R. L. Ives ... 781
Ploger, L. W. (With E. T. Apfel *et al.*): Possible diatreme in Syracuse, New York ... *1421*
Pollock, C. M.: Geological foundation of exploration for petroleum in Japan ... *1559*
Possible diatreme in Syracuse, New York. By E. T. Apfel, J. E. Maynard, and L. W. Ploger ... *1421*
— European correlatives of Wisconsin glacial substages. R. F. Flint ... *1438*
Practical significance of the petrographic characteristics of two Kansas coal beds. by W. W. Hambleton ... *1447*
Pray, L. C., and Sharp, W. N.: Bastnaesite discoveries near Mountain Pass, California ... *1519*
Pre-Cretaceous stratigraphy of the northern Klamath Mountains. By F. G. Wells, G. W. Walker and J. M. McIntyre ... *1514*
Pre-Huronian glaciation and early Huronian weathering and sedimentation in the Menominee District, Michigan. By J. W. Trow ... *1486*
Precambrian stratigraphy of Minnesota. By F. F. Grout, J. W. Gruner, G. M. Schwartz, and G. A. Thiel ... 1017
Predicted fabric changes (in deformed Yule marble). By J. W. Handin and David Griggs ... 863
Preliminary stratigraphic report of some California Eocene silicoflagellates. By Y. T. Mandra ... *1523*
Preservation of the texture of echinoderm plates in metamorphosed rocks. By W. H. Bucher ... *1548*
Press, Frank, and Ewing, Maurice: Two slow surface waves across North America ... *1528*
— (With Maurice Ewing): Surface waves at Honolulu ... *1526*
— (— —): Surface waves fror Atlantic earthquakes ... *1526*
— (— —): Surface waves from Solomon Islands Earthquake, 24 July 1950 ... *1527*
— (— —): Tide-gauge disturbances from the great eruption of Krakatoa ... *1527*
— (— — and J. L. Worzel): Further observations of the T phase ... *1527*
Problem of the carbonate apatites. IV—Structural substitutions involving CO_3 and OH. By Duncan McConnell ... *1463*
Problems in endoceroid classification. By R. H. Flower ... *1439*
— of alluvial-terrace mapping for the engineering geologist. By A. R. Leonard and John C. Frye ... *1460*
— — Minnelusa formation in the Black Hills. By J. P. Gries and D. A. Berg ... *1535*
Proctor, Dean (With T. S. Lovering *et al.*): Upper Ordovician, Silurian, and Devonian stratigraphy of the Tintic Mountains, Utah ... *1505*
Proctor, P. D.: Geological projections under volcanic cover, East Tintic, Utah ... *1470*
Proposed field conference for 1954: Baker, Oregon, to Rapid City, South Dakota. By T. C. Hiestand ... *1494*
— geomorphic evolution of continental terraces. By R. S. Dietz ... *1501*
Prouty, C. E.: "Leesport" and "Annville" formations of Pennsylvania ... *1471*
Provenience of pyroclastic materials. By C. S. Ross ... *1473*

Quam, L. O.: Geographic research program of the Office of Naval Research ... *1559*
Quantitative characteristics of mature erosional topography. By A. N. Strahler ... *1483*
— spectrochemical analysis of silicates: a scheme of analysis. By L. H. Ahrens ... *1420*

Rachou, J. F.: Tertiary stratigraphy of the Rattlesnake Hills, central Wyoming ... *1541*
Radioactivity and mountain building. By J. L. Rich ... 1179
Radon and thick source alpha determinations on deep-sea cores. By H. L. Volchok and J. L. Kulp ... *1487*
Recent history of Black Rapids glacier, Alaska. By T. L. Péwé ... *1558*
— mollusca and Tertiary correlations. By J. W. Durham ... *1522*
Reeves, Frank: Oil possibilities of Australia ... *1559*
Relation of factors affecting ground and rock temperature at shallow depths. By T. S. Lovering and H. D. Goode ... *1461*
— — folded Appalachians to the crystalline Appalachians in the light of Great Smoky Mountains geology. By P. B. King ... *1554*
— — micropegmatite to pegmatite at Safe Harbor, Pennsylvania. By W. H. Tomlinson ... *1485*
Replacement of the Middle Kittanning coal by interfingering clastics in southeastern Ohio. By W. M. Merrill ... *1463*

REPLOGLE, B. K. (With F. S. HONKALA and R. F. GOSMAN): Stratigraphy of the Phosphoria formation, Centennial Range, southwestern Montana 1537
Report on the third Conference on Carboniferous Stratigraphy and Geology at Heerlen, Netherlands, June 25-30, 1951. By J. A. Simon 1479
Restudy of the type Wasatch. By A. J. Eardley 1435
RETTY, J. A., and MOSS, A. E.: Iron-ore deposits of New Quebec and Labrador 1471
REVELLE, ROGER: Evidence of instability of Pacific basin. 1510
— and EMERY, K. O.: Barite concretions from the ocean floor 707
"Reverse drag" on high-angle faults in Oak Creek Canyon, Arizona. By Brainerd Mears, Jr. 1539
Revision of Devonian and Carboniferous sections, Nopah Range, Inyo County, California. By J. C. Hazzard .. 1503
Rhinoceros in basalt, lower Grand Coulee, Washington, Mold of a. By W. M. Chappell, J. W. Durham, and D. E. Savage 907
RICH, J. L.: Origin of compressional mountains and associated phenomena 1179
RICHARDS, H. G. (With JOHNSON, M. E.): Stratigraphy of the coastal plain of New Jersey 1556
RICHTER, C. F.: Check list on earthquakes with surface faulting 1528
—: Earthquake magnitude determination at Rome, Italy 1529
Riebeckite from St. Peter's Dome, Colorado. By R. G. Coleman 1517
RIGSBY, G. P.: Crystal-fabric studies on the Emmons Glacier, Mount Rainier, Washington 1510
RINEHART, C. D. (With S. L. MOORE): Geology of the Apex stock, Gilpin County, Colorado 1540
Ring structures in intrusive rocks of Nigeria, compared with their counterparts in New England. By Robert Greenwood 1151
Ripalta Field, a typical gas field of Po Valley, Northern Italy. By Vittorio Fois 1550
RISKA, DAPHNE (With C. W. WOLFE): Crystallography of jadeite (?) from near Cloverdale, California 1491
RITTENBERG, S. C. (With K. O. EMERY): Basin sediments off Southern California 1501
ROBERTSON, E. C.: New mechanical twinning in calcite .. 1472
ROBERTSON, FORBES, and MAURER, RUSSELL: Evidence bearing on the consanguinity of Missouri and Oklahoma Precambrian igneous rocks 1541
Robinsonite, a new lead antimony sulphide. By L. G. Berry, J. J. Fahey, and E. H. Bailey 1423
Rock glaciers in the Norman Wells area, N. W. T., Canada. By H. T. U. Smith 1480
ROEDDER, EDWIN: Composition and significance of fluid inclusions in minerals 1472
RODGERS, JOHN: Absolute ages of radioactive minerals from the Appalachian region 1560
Role of the hydrogen bond in the formation of some metastable phases. By A. J. Frueh, Jr. 1441
ROLSTON, J. W. (With P. D. TRASK): Engineering geology of San Francisco Bay, California 1079
ROSE, M. F. (With R. C. TREASHER): Foundation problems, Folsom Dam project, California 1513
ROSENFELD, J. L. (With J. B. THOMPSON, JR.): Tectonics of a mantled gneiss dome in southeastern Vermont .. 1484
ROSS, C. S.: Provenience of pyroclastic materials 1473
— and FOSTER, M. D.: Studies of minerals in dunites and in olivine-rich inclusions in basaltic rocks 1473
ROWLAND, R. A., and BECK, C. W.: Determination of small quantities of dolomite by differential thermal analysis 1473
ROY, D. M., and OSBORN, E. F.: The system MgO—Al_2O_3—H_2O 1474
ROY, RUSTUM, and OSBORN, E. F.: Phase equilibria in the system Al_2O_3—SiO_2—H_2O 1474
RUBEY, W. W.: Geologic history of sea water: an attempt to state the problem 1111
—: Structural pattern in the overthrust arc of western Wyoming and adjacent states 1475

Sagamore siltstone member (new name). By Wallace de Witt, Jr. 1347
Salite and actinolite at Iron Mountain, Missouri. By V. T. Allen and J. J. Fahey 1420
San Gabriel and related faults in the western San Gabriel Mountains, California. By G. B. Oakeshott 1509
San Francisco Bay, California, Engineering geology of. By P. D. Trask and J. W. Rolston 1079
San Manuel copper deposit, Pinal County, Arizona, Further biogeochemical data from. By H. V. Warren, R. E. Delavault, and R. I. Irish 919
SAUNDERS, D. F. (With J. M. PARKS, JR.): Age of mineralization: thermoluminescence and radioactivity of fluorite 1468
SAUNDERS, H. E.: Identification of features named by Amundsen in the Queen Maud Range 1560
SAVAGE, D. E.; OGLE, B. A.; and CREELY, R. S.: Subdivision of vertebrate-bearing nonmarine Pliocene rocks in west-central Contra Costa County, California 1511
— (With W. M. CHAPPELL and J. W. DURHAM): Mold of a rhinoceros in basalt, lower Grand Coulee, Washington 907
SCHAIRER, J. F., and YAGI, KENZO: System FeO—Al_2O_3—SiO_2 1475
SCHALLER, W. T., and CARRON, M. K.: Margarite-ephesite series; theory versus fact 1476
SCHEID, V. E.: Landslide caused by over-irrigation near Cambridge, Washington County, Idaho 1511
SCHMIDT, R. G. (With P. E. CLOUD, JR., and H. W. BURKE): Geology of Saipan, Mariana Islands 1499
SCHNEER, C. J.: Co-ordination models 1476
SCHOLTEN, ROBERT (With K. A. KEENMON and W. O. KUPSCH): Tectonic history of the Lima region, southwestern Montana and adjacent Idaho 1454
SCHWARTZ, G. M.: Chlorite-calcite pseudomorphs after orthoclase phenocrysts, Ray, Arizona 1476
SCHWARTZ, G. M. (With F. F. GROUT *et al.*): Precambrian stratigraphy of Minnesota 1017
SCLAR, C. B.: Coronites from the Preston gabbro, New London County, Connecticut 1477
SCOTT, J. R. (With E. R. LARSON): Helicoprion from Elko County, Nevada 1523
SCULL, B. J.: Development of melanterite and fibroferrite from gelatinous ferrous sulfate 1520
Seamounts
  Submarine geology of the Gulf of Alaska. By H. W. Menard and R. S. Dietz 1263
Secondary enrichment in Bolivian tungsten deposits. By N. N. Kohanowski 1538
— uranium deposits in the United States. By Frederick Stugard, Jr., D. G. Wyant, and A. J. Gude III 1542
Sedimentary facies changes in coal strata. By E. C. Dapples 1430
— — of the Lake Superior iron-bearing formation, and their relation to volcanism and geosynclinal development. By H. L. James 1452
— processes along the south shore of Lake Erie, vicinity of Sandusky, Ohio. By H. J. Pincus 1558
Sedimentation
  Barite concretions from the ocean floor. By Roger Revelle and K. O. Emery 707
  Glacial clays in Steep Rock Lake, Ontario. By Ernst Antevs 1223
— and stratigraphy of the Timiskaming series, Kirkland Lake, Ontario. By D. F. Hewitt 1450

Seismic-refraction measurements in the Atlantic Basin, Part II. By C. B. Officer, Jr., Maurice Ewing, and P. C. Wuenschel ... *1528*
Seward-Malaspina glacier system, Canada-Alaska, Accumulation and ablation of. By R. P. Sharp ... 725
SHARP, R. P.: Accumulation and ablation on the Seward-Malaspina glacier system, Canada-Alaska ... 725; *1512*
SHARP, W. N. (With J. C. OLSON): Geologic setting of the Mountain Pass bastnaesite deposits, San Bernardino County, California ... *1467*
— (— L. C. PRAY): Bastnaesite discoveries near Mountain Pass, California ... *1519*
Shellhammer Hollow formation (new name). By Wallace de Witt, Jr. ... 1347
SHEPARD, F. P.: Composite origin of submarine canyons. *1512*
† SHEPARD, F. P.: Submarine erosion, a discussion of recent papers ... 1431
— INMAN, D. L., and FISHER, R. L.: Marine beaches of the United States ... *1477*
SHOEMAKER, E. M.: Internal structure of the Sinbad-Valley-Fisher Valley salt anticline, Colorado and Utah ... *1478*
SHRODE, R. S. (With J. E. LAMAR): Water-soluble salts in limestone and dolomites ... *1456*
Sierra Nevada, California, Mount Lincoln—Castle Peak area. By F. S. Hudson ... 931
SIEVER, RAYMOND: X-ray diffraction studies of some physical components of coal ... *1478*
— (With H. D. GLASS): Occurrence of dolomites in the Pennsylvanian of Illinois ... *1443*
Signal butte igneous group. By E. H. Stevens ... *1541*
Significance of temperature upon the foraminifera from the deep basins off the Southern California coast. By R. W. Crouch ... *1521*
Siliceous sediments of Ouachita facies in Oklahoma. By August Goldstein, Jr., and T. A. Hendricks ... *1443*
Silicified Trenton trilobites from New York. By W. R. Evitt ... *1436*
Silurian quartzites of the Inyo Mountains, California. By C. W. Merriam ... *1508*
SIMON, J. A.: Report on the third Conference on Carboniferous Stratigraphy and Geology at Heerlen, Netherlands, June 25-30, 1951 ... *1479*
SIMS, P. K.: Structure of the magnetite deposits in the Dover district, New Jersey ... *1479*
Size and sorting in sediments. By J. C. Griffiths ... *1551*
SMITH, H. T. U.: Rock glaciers in the Norman Wells area, N. W. T., Canada ... *1480*
SMITH, J. H. (With R. W. LENKE and F. S. JENSEN): Linear crevasse fillings, outwash channels, and other similarly oriented glacial features in north-central North Dakota ... *1460*
SMITH, K. G.: Morphology and origin of large-scale and small-scale pediment forms compared ... *1480*
SMOTHERS, W. J., and CHIANG, YAO: Differential thermal curves of some Arkansas lignites ... *1480*
SMYTH, PAULINE: Fusulinidae in the Pennsylvanian of Ohio ... *1481*
SNYDER, F. G.: Stratigraphic studies of graywackes at Ducktown, Tennessee ... *1481*
SOCOLOW, A. A.: Modern fold in Texas ... *1481*
SOHN, I. G.: Evolution and stratigraphic significance of the late Paleozoic ostracode Coryellina ... *1482*
Soil mechanics, use of by geologist for foundation problems. By P. D. Trask and J. W. Rolston ... 1079
SOKOLOFF, V. P., and CARTER, G. F.: Time and trace metals in archaeological sites ... *1560*
— (With G. F. CARTER): Humisol ... *1506*
Solution depressions in diorite in North Carolina. By H. E. LeGrand ... *1458*
Some geologic characteristics of uranium-bearing vein deposits. By D. L. Everhart and R. J. Wright ... *1436*
— recent correlations of Indiana coals. By C. E. Wier ... *1489*
— uranium deposits in sandstone. By D. G. Wyant, E. P. Beroni, and H. C. Granger ... *1544*
SOSOKA, JOHN (With DAVID GRIGGS *et al.*): Deformation of the Yule marble: Part IV—Effects at 150°C. ... 1385
Sound waves in the atmosphere generated by a small earthquake. By Hugo Benioff ... *1525*
Southern California coastal paleogeography. By W. H. Corey ... *1500*
Space-time concept in geology. By L. W. LeRoy ... *1539*
Spore analyses applied to a coal correlation problem in southern Indiana. By G. K. Guennel ... *1445*
STAATZ, M. H. (With V. R. WILMARTH *et al.*): Uranium in fluorite deposits ... *1543*
Stability relations of clinochlore and cordierite in the system $MgO—Al_2O_3—SiO_2—H_2O$. By H. S. Yoder, Jr. ... *1493*
Status of summary coal-resource surveys, November 1, 1951. By Paul Averitt ... *1421*
† STEARNS, H. T.: Outcrop of Payette formation along Snake River near Hagerman, Idaho ... 1149
Steep Rock Lake, Ontario, Glacial clays in. By Ernst Antevs ... 1223
STEVENS, E. H.: Signal Butte igneous group ... *1541*
STEVENSON, R. E.: Marl facies of the lower Pierre in south-central South Dakota ... *1542*
— and EMERY, K. O.: Biological and physical-chemical conditions in Newport Bay, California ... *1482*
STOKSTAD, O. L.: Geologic problems in the design and construction of highways ... *1483*
† STOSE, A. J. (With G. W. STOSE): Blue Ridge Front—a fault scarp ... 1371
† STOSE, G. W., and STOSE, A. J.: Blue Ridge Front—a fault scarp ... 1371
STRAHLER, A. N.: Hypsometric function for small drainage basins ... *1561*
—: Quantitative characteristics of mature erosional topography ... *1483*
Stratal relationships of the Supai formation of central Arizona. By R. L. Jackson ... *1504*
Stratigraphic studies of graywackes at Ducktown, Tennessee. By F. G. Snyder ... *1481*
Stratigraphy
Cretaceous and Tertiary in parts of Maryland and Virginia. By N. H. Darton ... 745
Nankoweap group of the Grand Canyon Algonkian of Arizona. By C. E. Van Gundy ... 953
Pleistocene valley sediments of the Dugway area, Utah. By R. L. Ives ... 781
— and structure of Georgia crystalline rocks. By A. S. Furcron ... *1551*
—of Berea sandstone and associated rocks in northeastern Ohio and northwestern Pennsylvania. By Wallace de Witt, Jr. ... 1347
— — coastal plain of New Jersey. By M. E. Johnson and H. G. Richards ... *1554*
— — Minnesota, Precambrian. By F. F. Grout, J. W. Gruner, G. M. Schwartz, and G. A. Thiel ... 1017
— — Phosphoria formation, Centennial Range, southwestern Montana. By F. S. Honkala, B. K. Replogle, and R. F. Gosman ... *1495*
— — Pliocene vertebrate fossil locality near Prescott, Arizona. By D. L. Bryant ... *1496*
Stream gradients and Monterey sea valley. By A. O. Woodford ... 799
Streamlining of the Carolina bays. By H. E. LeGrand ... *1459*
Structural pattern in the overthrust arc of western Wyoming and adjacent states. By W. W. Rubey ... *1475*
— relations of Cretaceous and Tertiary formations in part of Maryland and Virginia. By N. H. Darton ... 745
— setting of the Kentucky-Illinois fluorspar district in the Eastern Interior Basin. By D. A. Carter ... *1533*

Structure
Deformation of Yule marble. By David Griggs and W. B. Miller ... 853
Deformation of Yule marble. By D. T. Griggs, F. J. Turner, Iris Borg, and John Sosoka ... 1385
Deformation of Yule marble. By J. W. Handin and David Griggs ... 863
Mount Lincoln—Castle Peak area, Sierra Nevada, California. By F. S. Hudson ... 931
Older Precambrian structure in Arizona. By C. A. Anderson ... 1331
Origin of compressional mountains and associated phenomena. By J. L. Rich ... 1179
— and copper mineralization at the Elizabeth Mine, Vermont. By Hugh McKinstry ... *1463*
— — origin of the northern Sangre de Cristo Mountains, Colorado. By J. W. Gabelman ... *1534*
— of Kisseynew gneisses in the Weldon Bay-Sherridon region, Manitoba. By J. Kalliokoski ... *1453*
— — magnetite deposits in the Dover district, New Jersey. By P. K. Sims ... *1479*
— — younger intrusive rocks of Plateau Province, Nigeria. By Robert Greenwood ... 1151
Structures in ice wedges of northern Alaska. By R. F. Black ... *1423*
Studies of metamict minerals. (I): Methods and Procedures. By Joseph Berman ... *1422*
— — minerals in dunites and in olivine-rich inclusions in basaltic rocks. By C. S. Ross and M. D. Foster ... *1472*
— — Pleistocene stratigraphy along Lake Erie in southwestern Ontario. By Aleksis Dreimanis ... *1432*
— — radioactive compounds: IV—Pitchblende from Lake Athabaska. By E. J. Brooker and E. W. Nuffield ... *1425*
Study of Seyler theory of coal reflectance. By J. T. McCartney ... *1462*
— — **some Bermuda rocks.** By Fred Foreman ... 1297
Stugard, Frederick, Jr.; Wyant, D. G.; and Gude, A. J., III: Secondary uranium deposits in the United States *1542*
Subdivision of vertebrate-bearing nonmarine Pliocene rocks in west-central Contra Costa County, California. By D. E. Savage, B. A. Ogle, and R. S. Creely. *1511*
Submarine canyons
Stream gradients and Monterey sea valley. By A. O. Woodford ... 799
† — erosion, a discussion of recent papers. By F. P. Shepard ... 1431
— **Geology of the Gulf of Alaska.** By H. W. Menard and R. S. Dietz ... 1263
† — topography in the North Atlantic. By B. C. Heezen, Maurice Ewing, and D. B. Ericson ... 1407
Sunken islands of the Mid-Pacific mountains. By E. L. Hamilton ... *1502*
Surface tension as an effective factor in gradation. By H. A. Ireland ... *1451*
— waves at Honolulu. By Maurice Ewing and Frank Press ... *1526*
— — from Atlantic earthquakes. By Maurice Ewing and Frank Press ... *1526*
— — — Solomon Islands earthquake, 24 July 1950. By Maurice Ewing and Frank Press ... *1527*
— — recorded by a Benioff vectorial seismograph. By B. Gutenberg ... *1527*
Syenites and nepheline syenites of Stettin, Marathon County, Wisconsin. By Elaine Geisse ... *1442*
Synthetic granites and their melting behavior under high H_2O pressures. By N. L. Bowen and O. F. Tuttle ... *1425*
System $FeO—Al_2O_3—SiO_2$. By J. F. Schairer and Kenzo Yagi ... *1475*
— $MgO—Al_2O_3—H_2O$. By D. M. Roy and E. F. Osborn ... *1474*
Taconic thrust in Sudbury, Vermont. By Marshall Kay ... *1554*
Taxonomic position of *Pentylus*. By J. A. Wilson ... *1490*
Taylor, E. F.: Geology and oil fields of Brasil ... *1561*
Tectonic history of the Lima region, southwestern Montana and adjacent Idaho. By K. A. Keenmon, W. O. Kupsch, and Robert Scholten ... *1454*
Tectonics of a mantled gneiss dome in southeastern Vermont. By J. B. Thompson, Jr., and John L. Rosenfeld ... *1484*
Tertiary basin delay at Fresno, California. By Don Tocher ... *1529*
— formations in part of Maryland and Virginia, Structural relations of. By N. H. Darton ... 745
— stratigraphy of Rattlesnake Hills, central Wyoming. By J. F. Rachou ... *1541*
— — — southeastern Wyoming and northeastern Colorado. By J. N. Minick ... *1540*
Test wall microstructure as a basis for separating *Nonion* and *Elphidium*. By O. L. Bandy and R. H. Merriam *1521*
Thayer, T. P. (With J. M. Axelrod *et al.*): Phosphate mineralization at Bomi Hills and Bambuta, Liberia, West Africa ... *1421*
Thermodynamic basis for a petrogenetic grid. By J. B. Thompson, Jr. ... *1484*
Thiel, G. A. (With F. F. Grout *et al.*): Precambrian stratigraphy of Minnesota ... 1017
Third Heerlen Congress of Carboniferous stratigraphy and geology. By J. S. Williams ... *1490*
Thompson, G. A.: Breccia pipes of the Terlingua district, Texas ... *1512*
Thompson, J. B., Jr.: Thermodynamic basis for a petrogenetic grid ... *1484*
— and Rosenfeld, J. L.: Tectonics of a mantled gneiss dome in southeastern Vermont ... *1484*
Threet, R. L.: Laramide structures in the Parowan Gap area, southwestern Utah, and their relation to the Colorado Plateau-Basin and Range boundary ... *1513*
Thrusting and chaos structure in the Silurian Hills, San Bernardino County, California. By D. H. Kupfer ... *1456*
Thwaites, F. T., and Bertrand, Kenneth: Pleistocene geology of the Door Peninsula, Wisconsin ... *1485*
Tide-gauge disturbances from the great eruption of Krakatoa. By Maurice Ewing and Frank Press ... *1527*
Tilton, George (With Harrison Brown *et al.*): Isotopic composition of lead and the ages of minerals in a Precambrian granite ... *1426*
Time and trace metals in archaeological sites. By V. P. Sokoloff and G. F. Carter ... *1560*
Tocher, Don: Tertiary basin delay at Fresno, California ... *1529*
Tollefson, O. W.: Geology of central Middle Park, Colorado ... *1542*
Tomlinson, W. H.: Relation of micropegmatite to pegmatite at Safe Harbor, Pennsylvania ... *1485*
Towle, C. C. (With J. W. Gruner and Lynn Gardiner): Uranium mineralization in Todilto limestone near Grants, McKinley County, New Mexico ... *1445*
Transportation of coarse material on alluvial fans. By J. P. Buwalda ... *1497*
Trantina, J. A.: Frost action on excavated slopes in Niobrara chalk, Fort Randall Dam, South Dakota ... *1543*
Trask, P. D., and Rolston, J. W.: Engineering geology of San Francisco Bay, California ... 1079
Travel times of waves from artificial explosions. By B. Gutenberg ... *1528*
Treasher, R. C., and Rose, M. F.: Foundation problems, Folsom Dam project, California ... *1513*
Trow, J. W.: Pre-Huronian glaciation and early Huronian weathering and sedimentation in the Menominee District, Michigan ... *1486*

Tumac Mountain, a postglacial cinder cone in Washington state. By A. T. Abbott ... 1495
TURNER, F. J., and CH'IH, C. S.: Deformation of Yule marble: Part III—Observed fabric changes due to deformation at 10,000 atmospheres confining pressure, room temperature, dry ... 887
— (With DAVID GRIGGS *et al.*): Deformation of the Yule Marble: Part IV—Effects at 150°C ... 1385
TUTTLE, O. F., and BOWEN, N. L.: Four series of alkali feldspars ... 1486
— (With N. L. BOWEN): Synthetic granites and their melting behavior under high H_2O pressures ... 1425
Two slow surface waves across North America. By Frank Press and Maurice Ewing ... 1528

Unconformities
Importance in Precambrian stratigraphy of Minnesota. By F. F. Grout, J. W. Gruner, G. M. Schwartz, and G. A. Thiel ... 1017
Underclay limestones. By G. M. Wilson ... 1490
Unit cell of hydromagnesite. By Joseph Murdoch ... 1465
— — — schairerite. By C. W. Wolfe and Alice Caras ... 1491
Upper Ordovician, Silurian, and Devonian stratigraphy of the Tintic Mountains, Utah. By T. S. Lovering, H. T. Morris, Dean Proctor, and John Lemish ... 1505
Uranium deposits, Beaverlodge area, Saskatchewan, Canada. By B. S. W. Buffam ... 1427
— in black shales, lignites, and limestones in the United States. By G. B. Gott, D. G. Wyant, and E. P. Beroni ... 1535
— — fluorite deposits. By V. R. Wilmarth, H. L. Bauer, M. H. Staatz, and D. G. Wyant ... 1543
— mineralization in Todilto limestone near Grants, McKinley County, New Mexico. By J. W. Gruner, C. C. Towle, and Lynn Gardiner ... 1445
Uranoan thorite and thorian monazite from blacksand paystreaks, San Mateo County, California. By C. O. Hutton ... 1518
Use of geophysical methods in the search for reefs. By H. W. Hoylman ... 1503
Utah
Pleistocene valley sediments of the Dugway area. By R. L. Ives ... 781

Vacuum differential thermal analysis of coal. By W. L. Whitehead and L. H. King ... 1489
Valley wave. By Perry Byerly and Jerry Eaton ... 1526
VAN GUNDY, C. E.: Nankoweap group of the Grand Canyon Algonkian of Arizona. By C. E. Van Gundy ... 953
Variations in differential thermal curves of low-iron dolomites. By D. L. Graf ... 1444
— — granitic rocks of the Huntington Lake area of the Sierra Nevada, California. By W. B. Hamilton ... 1447
Varves, simple, drainage, composite
Glacial clays in Steep Rock Lake, Ontario. By Ernst Antevs ... 1223
Vasquez series in the Upper Tick Canyon Area, Los Angeles County, California. By R. H. Jahns and W. P. Irwin ... 1504
Vein quartz in the Homestake ore body. By J. O. Harder ... 1494
Virginia, Structural relations of Cretaceous and Tertiary formations in. By N. H. Darton ... 745
Volcanic rocks in geosynclines. By Marshall Kay ... 1454
VOLCHOK, H. L., and KULP, J. L.: Radon and thick source alpha determinations on deep-sea cores ... 1487

WAGNER, W. R.: Microscopic study of an inclusion in the Idaho batholith ... 1543
WAHRHAFTIG, CLYDE: Frequency distributions as a test for theories of zoning in plagioclase ... 1520
WALKER, G. W. (With F. G. WELLS and J. M. MCINTYRE): Pre-Cretaceous stratigraphy of the northern Klamath Mountains ... 1514
WARMKESSEL, C. A., and GAULT, H. R.: Chemical characteristics of the Jacksonburg formation ... 1487
WANLESS, H. R., and MERRILL, W. M.: Evidence of eustatic change in sea level in the Pennsylvanian of the southwestern United States ... 1487
WARNER, L. A. (With W. T. HOLSER *et al.*): Notes on the geochemistry of beryllium ... 1450
WARREN, H. V.; DELAVAULT, R. E.; and IRISH, R. L.: Further biogeochemical data from the San Manuel copper deposit, Pinal County, Arizona ... 919; 1520
Washington
Mold of a rhinoceros in basalt, lower Grand Coulee. By W. M. Chappell, J. W. Durham, and D. E. Savage ... 907
Water-soluble salts in limestones and dolomites. By J. E. Lamar and R. S. Shrode ... 1456
WEAVER, C. E., and BATES, T. F.: Mineralogy, petrography, and petrology of the K-bentonites ... 1488
WEBB, R. W.: Faulted Paleocene of Ridge Basin, California ... 1488
WEEKS, D. H., JR.: Geographic work in New York State government ... 1561
WEIR, G. W.: Cross-lamination in the Salt Wash sandstone member of the Morrison formation ... 1514
WELLS, F. G.; WALKER, G. W.; and MCINTYRE, J. M.: Pre-Cretaceous stratigraphy of the northern Klamath Mountains ... 1514
WHITE, G. W.: Illinoian and Wisconsin drift of the southern part of the Grand River lobe in eastern Ohio ... 967
—: Pleistocene stratigraphy in northeastern Ohio ... 1489
WHITE, W. A. (With R. E. GRIM and W. F. BRADLEY): Petrology of the Paleozoic shales of Illinois ... 1445
WHITEHEAD, W. L., and KING, L. H.: Vacuum differential thermal analysis of coal ... 1489
WIER, C. E.: Some recent correlations of Indiana coals ... 1489
Wildcat group in the Eel River area, Humboldt County, California. By B. A. Ogle ... 1510
WILLIAMS, G. A.: Coal deposits and Cretaceous stratigraphy of the western part of Black Mesa, Arizona ... 1514
WILLIAMS, J. S.: Third Heerlen Congress of Carboniferous stratigraphy and geology ... 1490
WILMARTH, V. R., *et al.*: Uranium in fluorite deposits ... 1543
— (With W. T. Holser *et al.*): Notes on the geochemistry of beryllium ... 1450
WILSON, G. M.: Underclay limestones ... 1490
WILSON, J. A.: Taxonomic position of *Pastylus* ... 1490
WILSON, J. M. (With R. W. LANE): Geology of a Precambrian area near Rochford, South Dakota ... 1496
Winnipeg formation of Manitoba. By George Macauley and E. I. Leith ... 1461
Wisconsin drift of the southern part of the Grand River lobe in eastern Ohio, Illinoian and. By G. W. White ... 967
WITKIND, I. J.: Localization of sodium sulfate deposits in northeastern Montana and northwestern North Dakota ... 1544
WOLFE, C. W.: Blister hypothesis and the petrogenic cycle ... 1491
— and CARAS, ALICE: Unit cell of schairerite ... 1491
— and RISKA, DAPHNE: Crystallography of jadeite (?) from near Cloverdale, California ... 1491
WOOD, H. B.: Pillow-lava structure in amphibolite ... 1515
WOODFORD, A. O.: Stream gradients and Monterey sea valley ... 799
WORZEL, J. L. (With MAURICE EWING and FRANK PRESS): Further observations of the T phase ... 1527
WRIGHT, H. E., JR.: Opal cement in thick Tertiary eolian sandstone, Chuska Mountains, Arizona-New Mexico ... 1492
—: Physiographic reconnaissance in Iraqi Kurdistan ... 1492

WRIGHT, R. J. (With D. L. EVERHART): Some geologic characteristics of uranium-bearing vein deposits.... *1436*
WUENSCHEL, P. C. (With C. B. OFFICER, JR. and MAURICE EWING): Seismic-refraction measurements in the Atlantic Basin, Part II..... *1528*
WYANT, D. G.; BERONI, E. P.; and GRANGER, H. E.: Some uranium deposits in sandstone..... *1544*
— (With G. B. GOTT and E. P. BERONI): Uranium in black shales, lignites, and limestones in the United States..... *1535*
— (With FREDERICK STUGARD, JR., and A. J. GUDE, III): Secondary uranium deposits in the United States.... *1542*
— (With V. R. WILMARTH *et al.*): Uranium in fluorite deposits..... *1543*

X-ray diffraction studies of some physical components of coal. By Raymond Siever..... *1478*

YAGI, KENZO (With J. F. SCHAIRER): System FeO—Al_2O_3—SiO_2..... *1475*
Yardangs in South Dakota badlands. By C. L. Baker... *1532*
YEN, TENG-CHIEN: Fossil fresh-water mollusks and ecological interpretations..... 1375
YODER, H. S., JR.: Stability relations of clinochlore and cordierite in the system MgO—Al_2O_3—SiO_2—H_2O... *1493*
Younger intrusive rocks of Plateau Province, Nigeria, compared with the alkalic rocks of New England. By Robert Greenwood..... 1151
Yule marble, Deformation of. By David Griggs and W. B. Miller..... 853
— —, — —. By D. T. Griggs, F. J. Turner, Irish Borg, and John Sosoka..... 1385
— —, — —. By J. W. Handin and David Griggs..... 863
— —, — —. By F. J. Turner and C. S. Ch'ih..... 887

ZELLER, E. J.: New determinations of geologic age by the thermoluminescence method..... *1493*
Zinc
Biogeochemical data from the San Manuel copper deposit, Pinal County, Arizona. By H. V. Warren, R. E. Delavault, and R. I. Irish..... 919

32
75
93
51
53
85
63
87
93
19